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AERONAUTICAL ENGINEERING REVIEW

INSTITUTE OF THE AERONAUTICAL SCIENCES

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JANUARY 1952

AIRCRAFT: First Jet Carrier Photographic Plane, Navy

F2H-2P Banshee, Produced by McDonnell

ENGINE: Westinghouse J-34 Jet

METERING SYSTEM: Holley Turbine Control

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AERONAUTICAL ENGINEERING REVIEW

Cover—The Boeing B-47 Stratojet and the North American Sabre are shown in flight together for the first time in this recently released photograph taken somewhere over Kansas. These two aircraft, classed as "the fastest known bomber and fighter in the world," are both powered with J-47 jet engines, manufactured by General Electric Company. The Sabre, built by North American Aviation, Inc., holds the world's speed record of more than 670 m.p.h. The B-47, now in quantity production at the Wichita Division of Boeing Airplane Company, is also to be produced by Douglas Aircraft Company, Inc., at Tulsa, Okla., and by Lockheed Aircraft Corporation's Marietta, Ga., plant.

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Vol. 11 **JANUARY, 1952** **No. 1**

Contents

I.A.S. News 5
Editorial 8, 9

Articles

Power and Efficiency of Large Salt-Water Fish . . . . . D. R. Gero 10
The Viking Rocket . . . . . W. G. Purdy 16
On the Interaction Between Multiple Jets and an Adjacent Surface . . . . . Julius Jonas 21
Engineers for the USAF . . . Major Robert R. Lent 26
Aircraft Nuclear Propulsion . . . . M. C. Leverett 29
I.A.S. Previews 37

Reviews

Aeronautical Reviews 73
Books 99

Special I.A.S. Publications 20
I.A.S. Preprints 34
List of Corporate Members 70
Fairchild Publication Fund Papers 103
Personnel Opportunities 107
Index to Advertisers 112

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Pictured is the Chase XC-123
— prototype of the C-123

Chase C-123 Avitruc
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I. A. S. News

A Record of People and Events of Interest to Institute Members

W. E. Beall To Serve As 1952 I.A.S. President

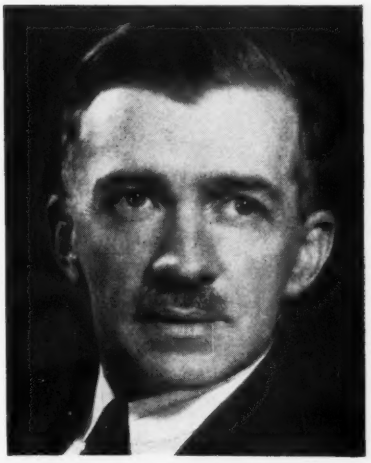
New President Succeeds Rear Adm. L. B. Richardson, U.S.N. (Ret.); New Vice-Presidents are P. R. Bassett, S. J. De France, E. H. Heinemann, and J. C. Leslie. C. H. Colvin Named Treasurer.

WELLWOOD E. BEALL will be inducted as the twentieth President of the Institute of the Aeronautical Sciences during the proceedings at the Honors Night Dinner, which will be held on January 28 at the Hotel Astor in New York City. He succeeds the present incumbent, Rear Adm. L. B. Richardson, U.S.N. (Ret.), who has supervised the affairs of the Institute during the past year.

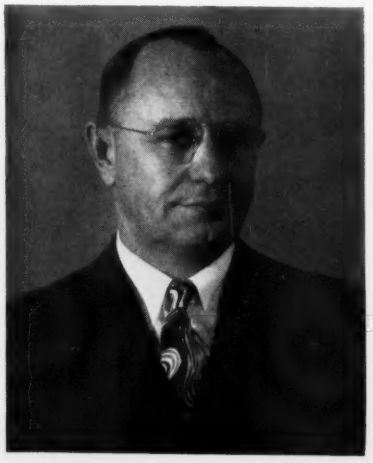
◂ **Other Elected Officers**—Those who will serve as I.A.S. Vice-Presidents for the ensuing year are: Preston R. Bassett, President, Sperry Gyroscope Company, Division of The Sperry Corporation; Smith J. De France, Director, Ames Aeronautical Laboratory, N.A.C.A., Moffett Field, Calif.; Edward H. Heinemann, Chief Engineer, El Segundo Plant, Douglas Aircraft Company, Inc.; and John C. Leslie, Vice-President, Pan American World Airways System. The new Treasurer for the forthcoming year is Charles H. Colvin, Director, Colvin Laboratories, Morristown, N.J. S. Paul Johnston has been re-elected Director of the Institute; Robert R. Dexter, Secretary; and Joseph J. Maitan, Controller.

The foregoing men will assume the duties of their elected positions at the Twentieth Annual Meeting, which runs from January 28 to February 1.

▸ **The President**—Mr. Beall, who is Vice-President of Engineering and Sales for Boeing Airplane Company, is a native of Cañon City, Colo., having been born there on October 28, 1906. He attended the University of Colorado for 4 years as an undergraduate student before transferring to the



I.A.S. Vice-Presidents for 1952: *Above is Preston R. Bassett; lower left, Smith J. De France; lower center, Edward H. Heinemann; and lower right, John C. Leslie. The pictures of incoming President Wellwood E. Beall and outgoing President L. B. Richardson will be found on pages 8 and 9 of this issue.*



1952 I.A.S. Treasurer, Charles H. Colvin.

Guggenheim School of Aeronautics at New York University for an additional year of study. He holds a Bachelor of Science degree in Mechanical Engineering and a graduate professional degree in aeronautical engineering.

His first position in the aeronautical field was with the Walter M. Murphy Company in the capacity of Assistant Chief Aeronautical Engineer. He stayed with this firm for a year and then resigned to accept a position as Instructor of Aeronautical Engineering at the Boeing School of Aeronautics. In 1934, he joined the staff of Boeing Aircraft Company as Sales Engineer; the same year, he was sent to Shanghai, China, as Boeing's Far Eastern Manager. After 2 years in the Orient, he returned to the States to become Chief Commercial Projects Engineer. In 1939, he was promoted to Chief Engineer and 4 years later was elected by the Board of Directors to the post of Vice-President of Engineering. Subsequently, he was placed in charge of sales, and on January 1, 1946, he took over his present duties as Vice-President of Engineering and Sales.

Mr. Beall is responsible for the design of Boeing aircraft. These have included: Model 314 Clipper; Model 307 Stratoliner; B-29 Superfortress; Model 377 Stratocruiser; C-97 Stratofreighter; B-47 Stratojet; guided missiles; and attendant engineering research.

Mr. Beall is an I.A.S. Fellow, a Past Officer, and a member of the I.A.S. Editorial Committee. He is also a member of the Society of Automotive Engineers and a frequent contributor to various scientific and engineering magazines. Mr. Beall served with the U.S. Naval Reserve as a Lieutenant (j.g.) from 1931 to 1939. (See photo, page 9.)

Consultants & Designers, Inc., Joins I.A.S.

The Institute welcomes as a new Corporate Member Consultants & Designers, Inc., of 251 W. 42nd St., New York, N.Y. This firm is one of the largest organizations in the country devoted exclusively to rendering design and drafting service to the nation's aircraft industry.

Consultants & Designers maintains a staff of over 600 engineers, designers, specialists, and draftsmen, who work in approximately 45,000 sq.ft. of air-conditioned, modernly equipped office space. They count among their clients such firms as The Glenn L. Martin Company; Goodyear Aircraft Corporation of The Goodyear Tire & Rubber Company; Pratt & Whitney Aircraft Division of United Aircraft Corporation; Airborne Instruments Laboratory, Inc.; Bendix Aviation Corporation; Minneapolis-Honeywell Regulator Company; Kaiser Metal Products; Reeves Instrument Corporation; and many others in the aircraft field.

The firm can carry out entire projects in its mid-Manhattan office or can supply engineering personnel from its own staff to conduct the work in a client's office. Services include complete airframe component engineering, electronic design, electromechanical design and development, production processing, tool, jig, and fixture design, plant layout, etc. Services such as these are rendered on "an extremely moderate" cost plus basis.

I.A.S. Corporate Members Win Awards

Awards for the best 1950 annual reports were presented on October 29 to the winning companies at the Annual Reports Dinner of *The Financial World*. The winning companies were selected after approximately 5,000 annual reports from 100 industrial classifications were covered and judged in the magazine's Eleventh Annual Survey.

The I.A.S. Corporate Members who were among the winners of bronze "oscars" and the classifications in which they won are: Aluminum Company of America—Aluminum Products; American Airlines System—International Air Lines; General Electric Company—Electrical Equipment; The Goodyear Tire & Rubber Company—Rubber and Tires; Lockheed Aircraft Corporation—Aircraft Manufacturing; and United Air Lines, Inc.—Domestic Air Lines.

General Electric Company won top honors for the best stockholder annual-meeting report.

Dr. B. A. Bakhmeteff Service

A memorial service for the late Dr. Boris A. Bakhmeteff, A.F.I.A.S., was held on October 18 in St. Paul's Chapel on the campus of Columbia University. The service was officially attended by the faculty of Columbia's School of Engineering who were garbed in full black academic robes.

Dr. Bakhmeteff, who died last July 21 of a heart attack at his home in Brookfield, Conn., was appointed to the faculty of Columbia's School of Engineering in 1931. Recently, Columbia University elevated him to the position of Honorary Professor of Civil Engineering, thus making him the fourth person in the University's history to acquire that title.

A Revision of Letter Symbols for Hydraulics

The American Standards Association Subcommittee Y10.2 (formerly Z10.2) Letter Symbols for Hydraulics, has recently been reconstituted for the purpose of reviewing and revising the 1942 Standards on Letter Symbols for Hydraulics.

The committee would appreciate receiving comments from interested parties concerning the 1942 Standards and any suggested additions or modifications thereof. It has been tentatively decided to consider the field of hydraulics as being concerned with all phases of the motion of liquids. An attempt will be made to include symbols in the field of hydrology and water-hammer. Suggestions and comments should be directed to the Chairman, Dr. J. M. Robertson, P.O. Box 30, State College, Pa.

New Engineering Center Planned

A $22,150,000 Engineering Center "to advance engineering education and science" has been planned by Columbia University. The plans for this new Engineering Center, as recently announced, provide for an Institute of Advanced Engineering Science and a Division of Cooperative Research in Engineering in addition to Columbia's School of Engineering founded in 1864.

Of the total amount involved in the Engineering Center program, $13,650,000 is earmarked for the building program, and the remaining $8,500,000 will go for professorships, fellowships, and scholarships.

The first unit of the Center is an existing four-story building at Riverside Drive and 125th St., New York, which is currently being remodelled. The second unit will be a 14-story, 250,000-

1951 Wright Trophy Winner

DR. JEROME CLARKE HUNSAKER was presented with the 1951 Wright Brothers Memorial Trophy at the Wright Memorial Day Dinner on December 17. This award, established 4 years ago by the National Aeronautic Association, is given for "significant public service of enduring value to aviation in the United States."

Dr. Hunsaker first became interested in aeronautics while working on his M.S. degree in hydrodynamics at Massachusetts Institute of Technology at the instigation of the U.S. Navy in which he was serving as a commissioned officer in the Construction Corps. In 1912—the same year in which he received his Master's—M.I.T. requested that he be detailed there by the Navy to establish research and teaching facilities in aeronautical engineering. After a period of investigating the development of aeronautics abroad, he assumed the task of establishing the facilities and a program for aeronautical engineering at M.I.T.

In 1916, Dr. Hunsaker received his D.Sc. degree for research on the dynamical stability of airplanes. He was then ordered to Washington and placed in charge of the Aircraft Division, Bureau of Construction and Repair, U.S.N. He continued in this post until 1923 when he became Assistant Naval Attaché in London, Paris, Berlin, Rome, and The Hague. In 1926, 18 years after his graduation from the United States Naval Academy, he resigned from active duty and the next year was appointed to the Volunteer Naval Reserve. He was promoted to Captain, U.S.N.R., in 1940 and 7 years later was transferred to the Retired list.

Dr. Hunsaker returned to M.I.T. in 1933 as Head of the Mechanical and Aeronautical Engineering Departments. After 1948, he continued as Head of the Department of Aeronautical Engineering. Last spring, he asked to be relieved of administrative responsibilities, but he agreed to remain on as a professor in the department until his retirement in June, 1952.

Dr. Hunsaker was a Naval member of the N.A.C.A. in 1922-1923 and a civilian member in 1938. He was appointed to his present office as N.A.C.A. Chairman in 1941.

An I.A.S. Founder Member, First President, Fellow, and Advisory Council Member, Dr. Hunsaker was the Editor of the JOURNAL OF THE AERONAUTICAL SCIENCES from 1934 to 1941. He is a leading member of various American and foreign engineering societies. Throughout his career, he has been active in many Government agencies and committees.

Dr. Jerome C. Hunsaker

. . . "Significant public service of enduring value to aviation in the United States."

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sq.ft. structure that will be erected as soon as the necessary funds are available. These two buildings together will more than double the present space used at Columbia for engineering training. The target date for the completion of this program is no later than 1954.

The Columbia University Engineering Center Development Fund, which was organized to seek the needed financing, launched its campaign at a fund-raising dinner on last November 7. "More than $2,000,000" of the total amount required was raised by the end of the dinner.

News of Members

▸ **William A. M. Burden,** I.A.S. Member, Founder Member and Benefactor, has moved the offices of his firm to 630 Fifth Ave., New York 20, N.Y.

▸ **Benjamin W. Chidlaw** (A.F.), Commanding General, Air Defense Command, Ent Air Force Base, Colo., has been promoted to the rank of full general.

▸ **Captain Walter S. Diehl,** U.S.N. (Ret.) (H.F.), formerly Assistant for Research Liaison, Office of Assistant Chief, Bureau of Aeronautics, U.S. Navy, was presented with the National Air Council's fourth annual award for outstanding achievement in aviation research and experiment. Specifically, Captain Diehl was cited for his contributions to the field of "flight in the transonic speed range to make possible the development of military and commercial aircraft

(*Continued on page 41*)

Rear Adm. L. B. Richardson, U.S.N. (Ret.)

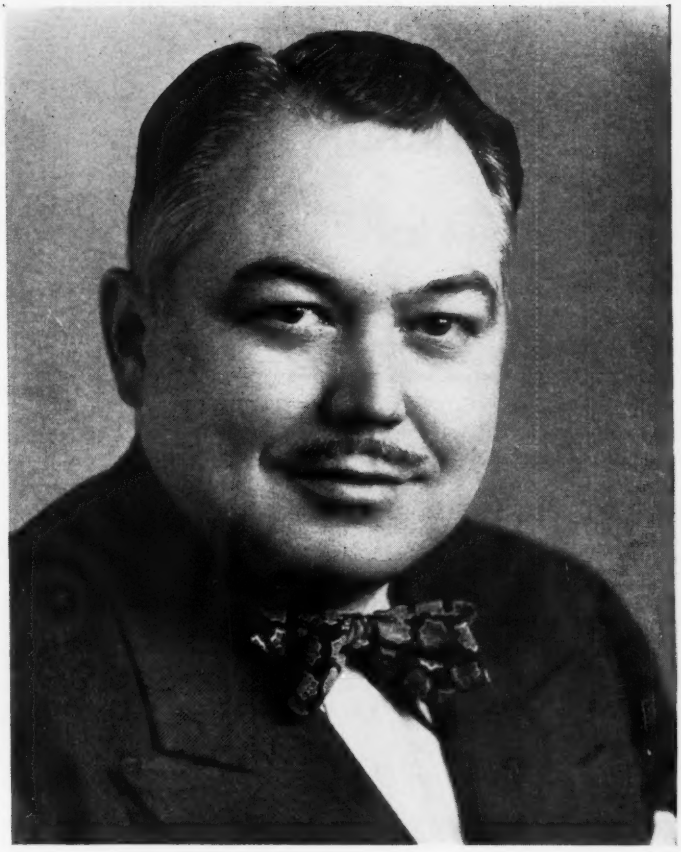
1951 I.A.S. President

"Well Done— Admiral!"

Those I.A.S. Presidents whose terms of office have bracketed an international meeting have certainly earned their keep! Admiral Richardson, our most recent incumbent, has more than ably maintained the high standards set by Preston Bassett in 1947 and William Burden in 1949 in "showing the flag" in foreign technical waters. We have all been proud of the way in which he conducted the affairs of the Institute at the meetings in England last fall. Neither the Institute, nor the country as a whole, could have had a more worthy ambassador to create good will and closer understanding in the field of the aeronautical sciences.

But Dick will be remembered, not alone as the leader of the Brighton Expeditionary Force of 1951, but as one who has made great contributions to the Institute during his term of office. He has given a great deal of time out of his normally busy life to the handling of Institute business. Beyond his personal leadership in the Council, in the Executive Committee, and the Finance Committee, he has visited many I.A.S. Sections from East to West and has himself presented a

Editorial



Wellwood E. Beall

"Welcome Aboard—Wellwood"

technical paper at an I.A.S. Meeting which was subsequently published in the REVIEW. The latter activity sets a new precedent for a president [no pun intended—ED.].

During the past year, the Institute has moved steadily ahead along the path marked out for it by its Council, as our Annual Report (presently to be published) will show. For whatever success has been attained, the Admiral must take a large share of the responsibility. We of the staff are particularly grateful to him for the support he has given to the day-to-day operations of the Institute.

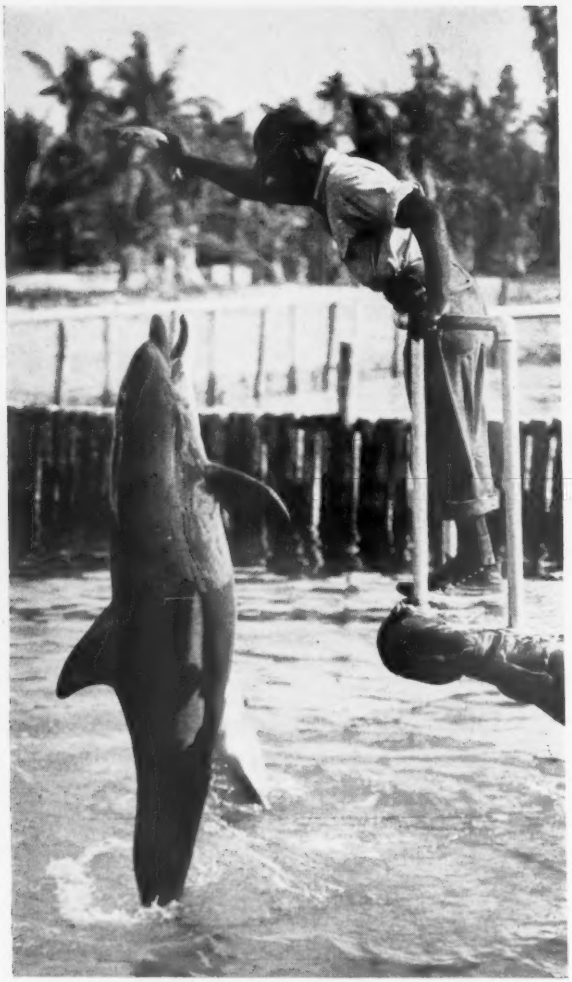
At the forthcoming Honors Night Dinner (January 28), our new President, Wellwood E. Beall, will formally take office. He is an old personal friend to most of us and a good and long-time friend of the Institute. We are all looking forward to a year of continuing activity and progress under his able and genial guidance. The staff, East and West, pledges to him the utmost in cooperation and assistance in the conduct of I.A.S. affairs during 1952. S.P.J.

1952 I.A.S. President

Power and Efficiency of Large Salt-Water Fish

D. R. GERO*

Goodyear Aircraft Corporation



The porpoise has sufficient power to drive itself vertically clear of the water, as illustrated by this American Museum of Natural History photograph.

SUMMARY

The information presented here represents a summary of the more important aspects of the theoretical and experimental work carried on by the Goodyear Aircraft Corporation in connection with the study of the *power* and *propulsive efficiency* of large salt-water fish and mammals. Although this work has been of a research nature and, in certain phases, needs additional substantiation, enough information is available to indicate that a further complete and comprehensive study of these animals should yield most valuable results.

The results specifically indicate that the large salt-water animals must possess a power loading (horsepower per pound of muscle) beyond what has normally been thought available, in addition to developing a favorable flow pattern equivalent to approximately 50 to 75 per cent laminar flow.

A complete hydrodynamic analysis of this problem is presented in reference 1.†

Received September 25, 1951. The experimental marine work accomplished in connection with this study was conducted at the Lerner Marine Laboratory, Bimini, British West Indies. This facility was made available to the Goodyear Aircraft Corporation through the courteous cooperation of Dr. C. M. Breder, Jr., of the American Museum of Natural History.

* Head, Applied Mechanics Section, Research & Development.

† This information is to be published in full in the *Novitates of the American Museum of Natural History.*

SYMBOLS

e	=	power loading, hp. per lb. of muscle
η	=	propulsive efficiency
ρ	=	water density, slugs per ft.^{3}
W_m	=	weight of fish muscle, lbs.
hp.	=	horsepower
C_{DT}	=	total drag coefficient, total drag/$[(1/2)\rho v^2 S]$
C_{DF}	=	form-drag coefficient
C_{Di}	=	induced-drag coefficient
g	=	32.2 ft. per sec.^{2}
S	=	total wetted area of body, ft.^{2}
D	=	drag, lbs.
C_f	=	friction-drag coefficient
C_f'	=	effective friction-drag coefficient
$C_{Dres.}$	=	residual-drag coefficient
m	=	per cent laminar flow
R	=	Reynolds Number
l	=	body length, ft.
W	=	weight of fish in air, lbs.
A	=	maximum cross-section area of body, ft.^{2}
v_0	=	free-stream velocity, ft. per sec.^{2}
F	=	Froude Number $= v/\sqrt{gl}$
l/d	=	fineness ratio of body
h/d	=	depth to diameter ratio of body
S'	=	tail area

A.R. = tail aspect ratio
Λ_{tail} = sweepback angle-tail
λ = tail taper ratio
T = net thrust max.
v = velocity, ft. per sec.

Introduction

The problem of fish propulsion is a most challenging one and a problem that has been investigated only from a somewhat philosophical standpoint for many years with no attempt directed toward a practical or engineering solution. A closer examination of the problem may partially explain this academic attitude, in that the solution to the problem is dependent upon an organism whose actions do not readily lend themselves to exact mathematical manipulations. In spite of this, certain realms of the activities of the fish‡ are based on the fundamental laws of hydrodynamics, kinematics, and stability which can be analyzed and evaluated objectively.

In recent years, the need for obtaining additional information on bodies maneuvering in a medium whose density is approximately equal to the density of the body itself has become more and more acute, particularly in the field of underwater and lighter-than-air craft. The fish performs certain functions, which, if duplicated or transferred in character to underwater or lighter-than-air craft, would greatly increase the value of these craft. The subject investigation was undertaken in an attempt to determine the manner in which fish so ably perform the swimming function, and, in the course of this study, to determine whether or not there were any basic features applicable to the improvement of the types of vehicles mentioned above.

Power Loading

The animals considered here are those that derive their power from the tail or flukes on the after part of the body. The thrust and associated control, as described in reference 1, are produced by a complicated oscillatory motion of the flukes characterized approximately by the superposition of a rotational motion onto a transverse motion of the tail. In its simplest form, this is similar to the well-known method of obtaining thrust from an airfoil or hydrofoil in a free stream by simply oscillating the surface in a direction normal to to the stream.

The forward thrust produced by the subject animals represents only the forward component of the total force developed by the tail. The energy available from this action is less than the total energy expended by the fish, depending on the propulsive efficiency of the particular tail configuration.

The term propulsive efficiency as used here is a rather elusive expression but has been defined as the efficiency of the tail in converting tail energy into forward energy with no considerations given to the thermal efficiency of converting food energy into mechanical energy. Although the thermal aspect has been considered in other studies, it is a physiological proposition and has not been pursued in this study.

As in the case of conventional engine nomenclature, it is convenient and appropriate to express the power of the "fish power plant" in terms of horsepower per pound of engine, or muscle. It has been determined that the muscular weight of the particular type of animals in question represents approximately 20 per cent of the total weight of the fish, a value that is used throughout the remainder of the investigation.

Since, in the steady-state condition, the power required by the fish is proportional to the drag and inversely proportional to the propulsive efficiency, the practical expression of power loading e as horsepower per pound of muscle becomes

$$e = Dv/550\eta W_m \tag{1}$$

where the total drag is

$$D = (1/2)\rho v^2 C_{D_T} S \tag{2}$$

C_{D_T} includes all drag terms reduced to the surface area of the fish and is represented as

$$C_{D_T} = C_{D_f} + C_f + C_{D_i} \tag{3}$$

Previous calculations and available references indicate that, for high Reynolds Numbers and for C_{D_T} and C_f based on the same representative area, Eq. (3) can be simplified to

$$C_{D_T} = 1.22C_f \tag{4}$$

‡ Included in this study is a single species of porpoise as well as fishes. No distinction is made in the text where it is evident that one or the other is excluded from the discussion.

A series of frames from the movie film taken by the author during the tests.

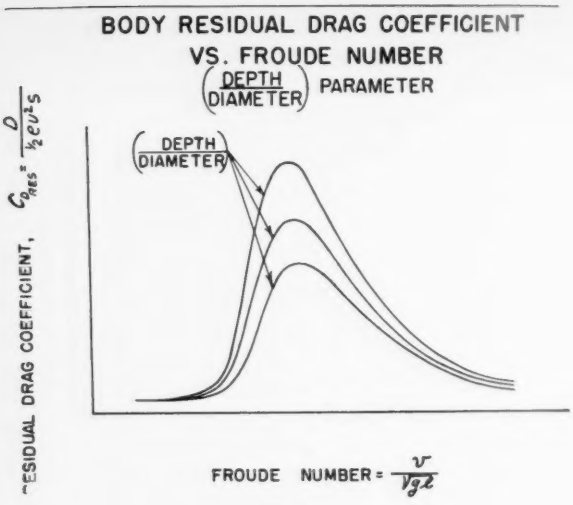

BODY RESIDUAL DRAG COEFFICIENT
VS. FROUDE NUMBER
(DEPTH / DIAMETER) PARAMETER
RESIDUAL DRAG COEFFICIENT, $C_{Dres} = \frac{D}{\frac{1}{2}\rho V^2 S}$
(DEPTH / DIAMETER)
FROUDE NUMBER = $\frac{V}{\sqrt{gl}}$

FIG. 1.

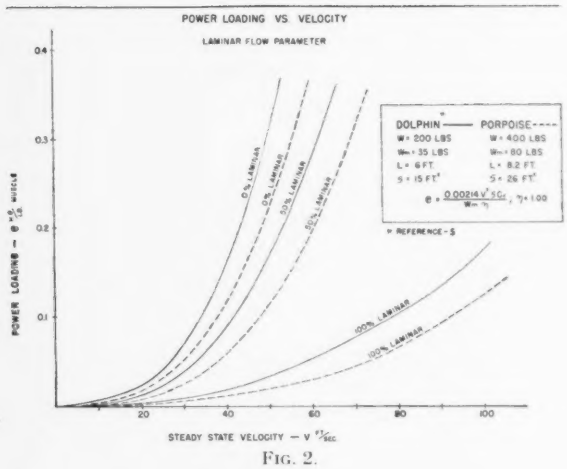


FIG. 2.

Substituting Eqs. (2) and (4) into the original expression (1), we find that

$$e = (0.00214v^3SC_f)/\eta W_m \qquad (5)$$

The C_f term in its original form, as frictional drag coefficient, does not completely satisfy the purpose at hand, since the present study is directly concerned with the character of flow and not simply a singular drag value at a particular Reynolds Number.

Therefore, a new and more appropriate expression C_f' has been introduced which permits a more accurate interpretation of the flow conditions present:

$$C_f' = [1 - (m/100)]C_{fT} + (m/100)C_{fL} \qquad (6)$$

where

m = per cent laminar (100 per cent, 50 per cent, etc.)

C_{fT} = turbulent friction coefficient for particular Reynolds Number (reference 3)

C_{fL} = laminar friction coefficient for particular Reynolds Number (reference 3)

By substituting C_f' for C_f in Eq. (5), the total expression then becomes

$$e = \frac{0.00214v^3S}{\eta W_m}\left[\left(1 - \frac{m}{100}\right)C_{fT} + \frac{m}{100}C_{fL}\right] \qquad (7)$$

Thus, Eq. (7) presents a convenient means of representing the relationship between power loading required and flow or frictional drag character of a particular body under various conditions.

To digress briefly, it was discovered as a result of the author's examination of past methods of determining the drag of the subject animals and subsequently power, that no consideration had been given by others to any form of resistance except friction drag. Even though this value is important, and in most cases represents 60 to 80 per cent of the total drag, a serious error may be made by neglecting all other forms of resistance.

The most important drag terms that have been neglected are:

(1) *Induced drag*, which is associated with the oscillatory motion of the fish's tail and manifests itself as lost energy or turbulence in the wake.

(2) *Residual drag* is composed of two separate terms; (a) form drag, C_{Dp}, which results from the three-dimensional character of the body and (b) a secondary correction ΔC_f of the friction drag which results in transferring from a flat plate to a three-dimensional body.

(3) *Froude Number* effect of the residual drag can, under certain maneuvering conditions, create large discrepancies in the total drag (see Fig. 1). This effect becomes critical for relatively low values of (depth ÷ diameter), and it should be given careful consideration since estimated speeds and consequently horsepower estimates have been made by observing the fish in relatively shallow water where conditions accompanying low (depth/diameter) ratios are in effect.

By way of illustration, consider the values for the whale given in reference 2 as expanded by the author below:

l = 84 ft.
W = 200,000 lbs.
S = 2,800 ft.²
v_0 = 15 knots
R = 1.25×10^8
F = 0.484
l/d = 7.00 (approx.)
h/d = 1.70 (approx.)

Examination of these values reveals that the Froude Number of 0.484 at 15 knots is in the critical region for bodies of fineness ratio 7.00. This results in an increase of $C_{Dres.}$ many times the normal value and will obviously require a considerable increase in the calculated horsepower available.

Returning to Eq. (7) in order to illustrate its real meaning, three large marine animals were investigated, the general geometric characteristics of which have been presented in references 1 and 5.

The first of the three animals investigated was the porpoise (Tursiops Truncatus) studied by the author at Bimini. Since it was not possible to actually handle this animal, the following geometrical and weight data are approximate:

l = 8.2 ft.
W = 400 lbs.
W_m = 80 lbs.
S = 26 ft.^{2}
S' = 0.82 ft.^{2}
A.R. = 2.5
Λ = 30°
λ = 0.5

The data for the second animal investigated, a dolphin, was taken from reference 5 and is listed below:

l = 6.0 ft.
W = 200 lbs.
W_m = 35 lbs.
S = 15 ft.^{2}

The third animal was not so large as the two preceding ones but was more completely studied since it was possible by means of a special mechanical rig (see picture on page 15) to determine the actual net available thrust and maximum terminal velocity. The operation of this rig is completely explained in reference 1. The general characteristics of the third animal, a barracuda (Sphyroena Barracuda), are as follows:

l = 4.0 ft.
W = 20 lbs.
W_m = 4.0 lbs.
T = 38 lbs.
v_0 = 40 ft. per sec.

Fig. 2 represents a summary of the information obtained for the porpoise and dolphin, using Eq. (7), and is presented as power loading versus velocity for various percentages of laminar flow. Since the present work has not proceeded to the point of determining actual propulsive efficiency values, η has been assumed to be 1.00. This is conservative and linear adjustments will be required when the actual values are eventually known.

Upon examination of Fig. 2, several interesting observations can be made. In the first place, the slopes of the curves decrease with increase in body size. This is to be expected since

$$e = \text{Power/Weight} \approx 1/(\text{Weight})^{1/3}$$

This can be seen from the fact that for geometrically similar bodies the required horsepower varies as the surface area, and the weight of muscle varies approximately as the weight or displacement of the body. Secondly, from Fig. 2, for presently accepted values of e in the order of 0.01, it is apparent that for reasonable values of velocity[4] (40 ft. per sec.), the flow must be approximately 100 per cent laminar. This appears to be, on the basis of the present state of the art, too optimistic. However, it is indicated, as has been substantiated by the following barracuda information, that values of e greatly in excess of 0.01 can be obtained.

On the basis of this, a compatible solution would be obtained with values of e in the order of 0.10 and corresponding drag values approaching 50 to 75 per cent laminar flow.

Fig. 3, which summarizes the barracuda study, indicates that for values of 40 ft. per sec. which were actually measured, values of e = 0.15 to e = 0.20 can be expected if the characteristic flow is 50 to 75 per cent laminar.

The results of the above analysis indicate that additional work must be initiated to investigate the physiological processes of the subject animals in order to more accurately define the limit of power loading. At the same time, further hydrodynamic work must be initiated to determine the manner in which it becomes possible for these animals to obtain such favorable flow conditions and corresponding low drag values.

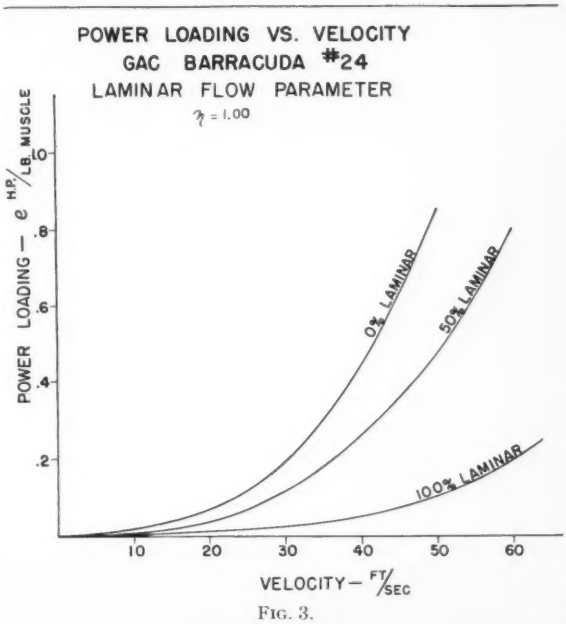


FIG. 3.

The barracuda, the fish that was studied in Fig. 3.

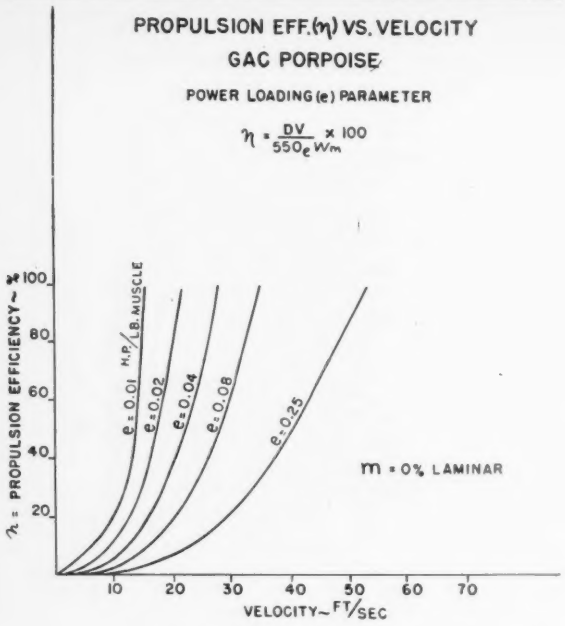


FIG. 4.

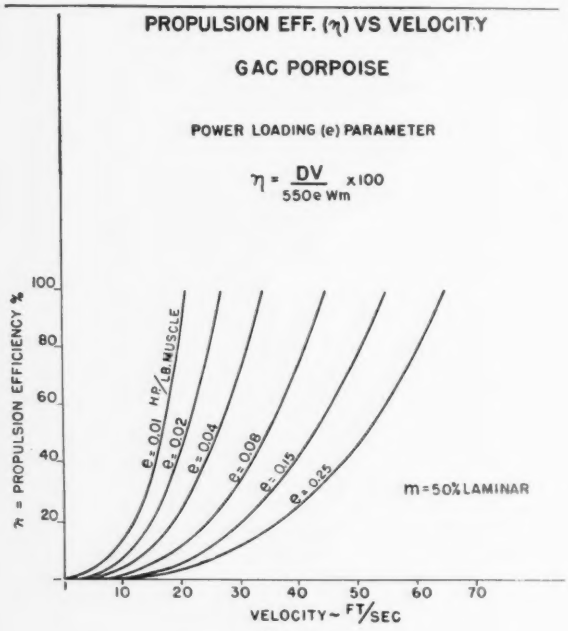


FIG. 5.

PROPULSIVE EFFICIENCY

Propulsive efficiency, as previously defined, shall be construed for the present purpose to mean the efficiency with which the subject animals convert the tail energy into forward thrust. The state of development of the general problem of fish propulsion has not progressed to the point where an exact experimental or analytical analysis can be made. Experimentally, one immediately becomes involved in food-energy input, basal metabolism, and such subjects, which in themselves are not as yet clearly defined. The large number of variables and unknowns involved in a completely analytical solution casts a dubious shadow on the results of such an analysis.

Having evaluated the phases mentioned above, there appears to be one method, a semiempirical method, which represents a logical beginning for an analysis of this type. This does not yield exact efficiency values but rather indicates what values must be obtained to satisfy known or approximated conditions.

Eq. (7) can be rewritten and used for this purpose, since it involves all of the important variables. In its revised form it becomes

$$\eta = \frac{0.00214v^3S}{eW_m}\left[\left(1 - \frac{m}{100}\right)C_{fT} + \frac{m}{100}C_{fL}\right] \quad (8)$$

The porpoise previously mentioned has been used as an illustrative example for this analysis. The results have been summarized and are presented in Figs. 4, 5, and 6 for $m = 0$, 50, and 100 per cent laminar-flow conditions, respectively. Each figure represents e versus velocity, using m as a parameter.

If it is assumed that the porpoise tail is as efficient as a conventional propeller using $\eta = 75$ per cent, several interesting observations can be made. From Figs. 4, 5, and 6 at 40 ft. per sec., the power loadings must be 0.175, 0.08, and 0.017, respectively.

These results in effect substantiate the previous conclusions with the most reasonable condition being a 50 per cent laminar flow with $e = 0.08$.

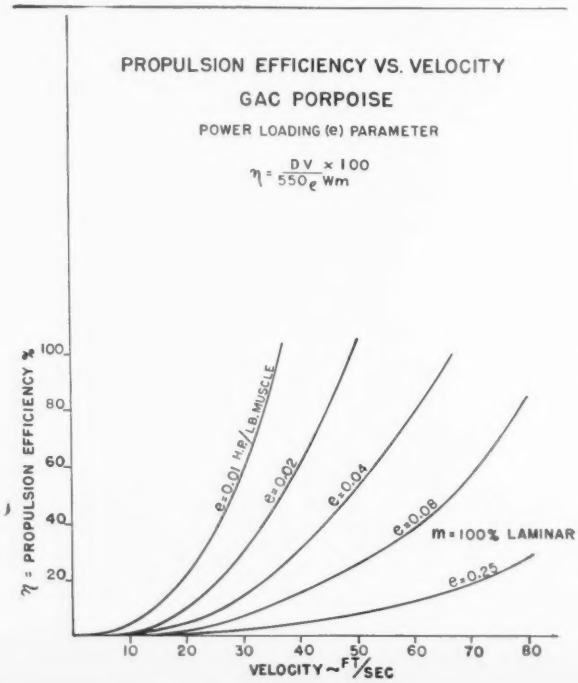


FIG. 6.

Second, for $v_0 = 40$ ft. per sec. using $e = 0.01$, which is the presently accepted value, the efficiency must be greater than 100 per cent for any flow condition, which is not possible.

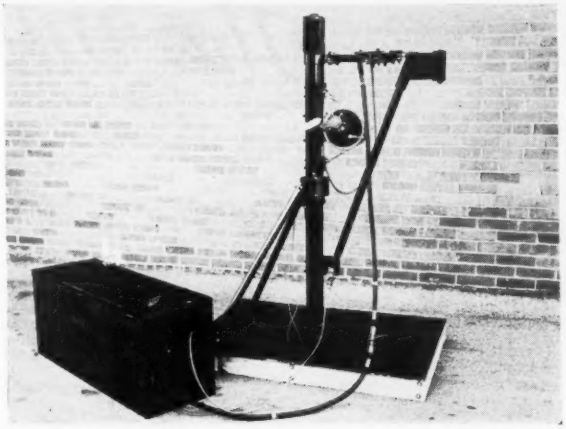
Therefore, it is apparent that reasonable efficiencies can only be obtained by an increase in presently accepted power-loading values coupled with the presence of flow conditions of approximately 50 to 75 per cent laminar.

Conclusions

(1) The determination of the fish's drag and the subsequent substantiation of power loading e (hp. per lb. muscle) has been, in the past, based purely on the skin-friction drag with no consideration given to any other form of resistance. This practice is in error and has led to erroneous conclusions.

(2) Presently accepted power-loading values and drag coefficients are incorrect, and some compromise must be reached. Reasonable propulsive efficiencies can only be obtained by an improvement in power loading accompanied by a decrease in the total drag coefficients.

(3) The improvement in power loading must be accomplished through a physiological approach, while the drag improvement can be realized only by further analyzing the hydrodynamics of the "real swimmers" such as tuna, which were not available for the above program.



Goodyear Aircraft Corporation piscatometer.

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The Viking Rocket

W. G. PURDY*
The Glenn L. Martin Company

ABSTRACT

The Viking Project is worthy of note not only because of the unique design problems associated with the development of a large liquid rocket-powered vehicle, but also because it represents a case history of development of a member of the pilotless aircraft family.

Designed to fulfill a Naval Research Laboratory requirement for a vehicle to carry research equipment into the upper atmosphere, the program is based upon development and test of an initial quantity of ten articles.

Results of tests with the first six rockets have established the soundness of the basic design assumptions and have demonstrated the need for emphasis on functional design considerations from inception of a program of this sort.

Quantitative data obtained from these flights have been satisfying not only because they have demonstrated good performance (Vikings 4 and 5 reached record altitudes for American-built aircraft of 105 and 107 miles, respectively) but because they have permitted determination of the causes for failures when such occurred.

ORIGIN OF THE VIKING

THE NEED FOR THE VIKING was established in December, 1945, when the Rocket Sonde Research Section was organized by the Naval Research Laboratory for the purpose of extending atmospheric research by use of rockets to altitudes above 25 miles. First experiments were started in early 1946, using captured German A-4 rockets, but, because the A-4 was somewhat limited both in usability and quantity, the Naval Research Laboratory established a requirement for a vehicle to be designed specifically for upper air research.

Since the A-4 represented the most advanced usable rocket design at that time, the Viking (then known as HASR-II) requirements were based upon the general characteristics of the German missile. Smaller in dimensions than the A-4, the Viking, as initially conceived, was to be capable of carrying instrument pay loads of up to 500 lbs. to altitudes above 100 miles on a stable, nearly vertical trajectory. Like the A-4, it was to be equipped with a liquid rocket power plant that utilized a steam driven pumping system to deliver the propellants (alcohol and liquid oxygen) to the thrust cylinder. The steam was to be obtained by catalytic decomposition of high concentration hydrogen peroxide. The vehicle was to be maintained on a nearly vertical heading by an automatic stabilization system using gyroscopes as error sensers. In addition, aerodynamic stability was to be provided by means of fins.

In the summer of 1946, The Glenn L. Martin Company and the Office of Naval Research signed a contract calling for development of a vehicle to meet NRL's requirements through manufacture and field test of an initial quantity of 10 articles. It was apparent that needed design data, which were then nonexistent, could be obtained only by actual flight test. Hence, to permit application of these data to the design as early as possible, the contract provided for progressive incorporation of changes in each rocket resulting from tests on the preceding vehicle.

This concept of consecutive change and test formed the basis for the program philosophy. The initial development was to be as complete as existing data permitted, but the necessity for firing the first rocket at an early date was not to be de-emphasized. After that point, the firing rate would be determined by the time required to incorporate changes indicated by previous flights.

Development of the power plant was handled under separate contract between the Bureau of Aeronautics and Reaction Motors Incorporated. On completion of this development, power plants for the rockets were to be provided under direct subcontract between Martin and RMI.

INITIAL DESIGN CONSIDERATIONS

While it can properly be called an aircraft, many of the initial design problems and considerations presented by Viking were radically different from those that normally confront the aircraft designer. These problems stemmed largely from the unconventional nature of the rocket's flight, which, as Fig. 1 shows, can be divided into three phases—viz., powered flight, free fall, and re-entry. For the most part, the rocket is designed by the conditions obtaining during the first phase. It is during this short interval that the missile gathers the momentum necessary to carry it to peak altitude during the second phase. Since the rocket must enter the second phase on a stable vertical heading, these conditions must be maintained during the first phase also. Of course, the rocket is expected to stay together! The 20,000 lbs. of thrust applied by the power plant over this 1.25-min. period accelerate the vehicle to a velocity of over 5,000 ft. per sec. The rapid and large-scale changes in altitude (and, hence, atmospheric pressure) and air loads produce operating

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* Project Engineer, Viking Project.

conditions during the powered flight period which may be variable.

During the stillness of the second phase, the Viking spends about 5.5 min. coasting to peak altitude and back to 130,000 ft. Although the rocket proper is almost dead, it is this phase that justifies the Viking's existence, since it is from this region that most of the upper air research data are desired. Aside from the instruments that make up the pay load, the only active part of the rocket is the coasting flight stabilization system that is required to trim out residual heading errors remaining at the end of powered flight.

The beginning of the third or re-entry phase is marked by the region where the atmosphere becomes dense enough to turn the rocket over so that it approaches the earth nose first. At this point, the Viking has completed its mission except for operations to improve the chances for recovery of parts of the rocket after impact. These operations consist of detonation of explosive charges located in the rocket in such a way that the rocket is severed into two or more unstable sections. Since the terminal velocity of the sections is considerably lower than that of the intact rocket, the chances for recovery of undamaged parts of the rockets are increased. This is particularly important in the case of research data that have been recorded upon photographic film.

Depending upon the effectiveness of the blow-up operation in slowing the descent of the rocket, the impact occurs 5 to 10 min. after launching.

While a general picture (as above) as to what conditions the rocket could be expected to undergo could be drawn with the information at hand, that information was not sufficiently complete to provide satisfactory answers to all of the initial questions, and the blank spaces had to be filled by assumptions based upon theory and judgment.

The major design considerations and their influence on the configuration of Viking (Fig. 2) can best be pointed out in a summary of the design itself.

The external configuration was determined almost exclusively by aerodynamic considerations. A body with a high slenderness ratio was picked to minimize drag, and four fins were added at the aft end of the

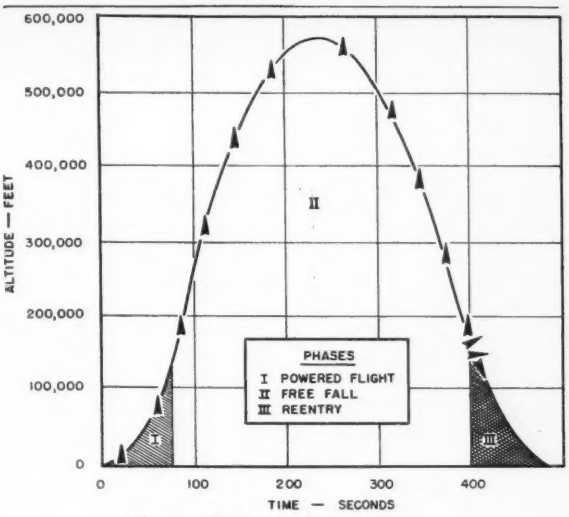

FIG. 1. Rocket trajectory phases.

body to provide aerodynamic stability. Actually, these characteristics had been generally accepted in the early stages of design when little aerodynamic data were available. Subsequent analysis indicated that neither of these was necessarily a controlling factor in the design. Calculations showed the amount of thrust energy required to overcome drag to be relatively small, and the importance of aerodyanamic stability was lessened when it became apparent that the control system would be required to provide all stability at launch and at the end of powered flight when aerodynamic forces were negligible. Nevertheless, the slim finned configuration was maintained. The balance of the design had been tailored to it by this time, and no compelling reasons for change arose.

The design of the control system was determined by the necessity, just stated, for this system to keep the vehicle stable without the aid of aerodynamic forces at launch when velocity was small and again at the end of powered flight when air density was essentially zero. This required that energy generated by the rocket be used in the form of reaction forces to produce the necessary controlling moments. A small part of the

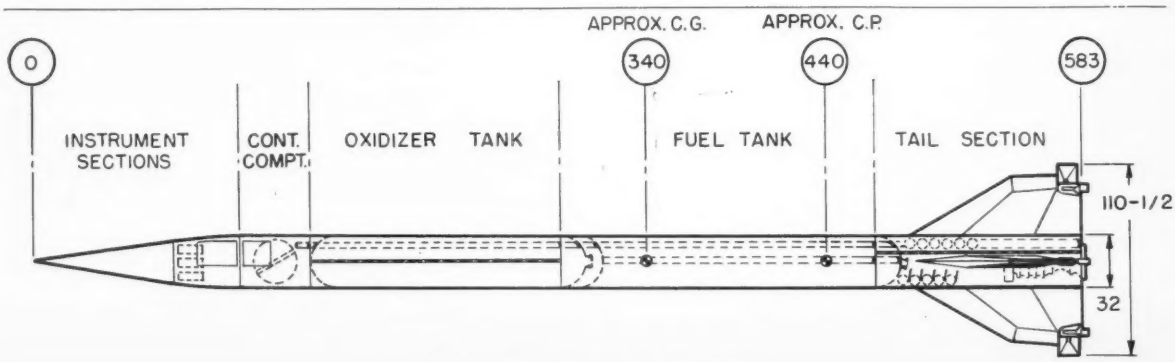

FIG. 2. Viking general configuration.

FIG. 3. Static firing Viking 5 at White Sands Proving Ground.

thrust energy was made available for control about the pitch and yaw axes by providing a means of deflecting the line of thrust with respect to the rocket's longitudinal axis. Rocket heading errors were detected by the gyros and the resulting signals, after passing through appropriate amplifier and derivative circuits commanded the servos to operate to produce a thrust component normal to the rocket's axis of the proper magnitude and sense to correct the error in heading.

Similarly, roll-control moments were provided by ducting the exhaust steam from the turbine through an opposite pair of the fins to directable exhaust nozzles near the fin tips. In addition, controllable tabs were installed at the tips of the same two fins that contained the roll jets. The tabs provided additional roll-control moments during the period when disturbances from aerodynamic forces could be expected to be present.

It was probable that residual heading errors would be present at the beginning of coasting flight, since disturbances could be expected in connection with power-plant shutdown that the main control system would not have time to correct. Changes in the direction of the thrust line during the shutdown transient and torques resulting from deceleration of the turbine were looked upon as the primary destabilizing forces at this point. Based on assumptions of the magnitude of these forces, it was determined that the pressurizing gas remaining in the storage sphere and propellant tanks contained sufficient energy to stabilize the rocket during the coasting period. Accordingly, small exhaust jets utilizing the pressurizing gas as a thrust medium were located to provide control about all three major axes as directed by the gyros.

As indicated earlier, the vehicle was to be equipped with a liquid rocket power plant using liquid oxygen and alcohol as propellants and designed to generate a thrust at sea level of 20,000 lbs. for approximately 75 sec. Centrifugal pumps driven by a steam turbine were provided to deliver the propellants to the thrust cylinder at the necessary rate. As previously stated, the steam was produced by catalytic decomposition of high concentration hydrogen peroxide. The propellants were stored in tanks in the mid-section of the rocket.

Given a completed design, the greatest single factor influencing the performance of a rocket is the operating time of the power plant. For example, in the initial Viking design, a reduction of 5 per cent in power-plant operating time causes a reduction in maximum altitude of approximately 25 per cent. To assure maximum usage of propellants, the power plant must operate at a mixture ratio during flight which will empty both tanks simultaneously. In opposition to this, the in-line configuration of the propellant tanks coupled with the increase in longitudinal acceleration causes enormous unbalances between the heads on the pump inlets. To provide some measure of regulation on the pump inlet heads, a controllable increment of pressure head was added to each propellant system in the form of regulated gas pressure. Since it was not practical to fully compensate all flight effects by this means, the remaining unbalance was minimized by designing the system for operation at the mean flight mixture ratio.

Structural design of the Viking was, in general, straightforward. Standard aircraft techniques were applied, except in the case of the propellant tanks, which were called upon to perform the dual purpose of pressure vessel and primary structure. Aluminum alloys were used throughout, except for the skin on the fin leading edges and on the nose which was made of stainless steel in anticipation of high skin temperatures resulting from aerodynamic heating.

RESULTS OF TESTS

The proof of the pudding began in January, 1949, when Viking No. 1 was delivered to White Sands

Proving Ground, N. M. Since that time, six rockets* have been fired. In each case, the launching has been preceded by an extended period of careful test and retest, including a captive firing (Fig. 3) to prove the operation and adjustment of the power plant. This test period has proved to be nearly as valuable as the actual flight of the rocket, since it has established the importance of another design consideration—that of functional design. A component or system almost always has some functional requirement other than that dictated by the ultimate mission. It has to be capable of undergoing test to prove its adequacy for the mission. A component may have to be removable, replaceable, and/or adjustable, and these factors should be realized with a minimum amount of strain on the part of the individual performing the task.

The test periods preceding the firings of the first three Vikings were all extended by component malfunctions. Viking 1, after continued difficulty with the oxidizer tank vent valves, experienced a small fire during the first static firing. The fire was traced to a steam leak through the flange of the turbine case. Because the turbine was almost inaccessible, the rocket was returned to the hangar and was unspliced, and the turbine case gasket was replaced. After a second static firing indicated the steam leak had been fixed and after more difficulty with the vent valves, the rocket was launched on May 3, 1949, to an altitude of 50.4 miles. The power plant shut down prematurely at about 53 sec., apparently from internal causes. Operation of the control system was excellent.

Viking 2 arrived at White Sands in July, 1949, equipped with a redesigned oxidizer tank vent valve, but, as the static firing disclosed, the turbine case leak was still present. Because the arrangement of components had been improved somewhat over Viking No. 1, the leak was repaired with the rocket in the vertical position. Instrumentation difficulties and a leak in the oxidizer pump seal delayed the firing until September 6. After 49.5 sec., the power plant shut down, again from internal causes. The control system operated normally, and the rocket reached a peak altitude of 32.3 miles.

As a result of tests and review of the telemetered data, it was concluded that the steam leak had recurred on both Viking 1 and 2 and that the resulting fire had caused shutdowns by damage to the electrical system. While the turbine case was being redesigned and external conduits were being added to carry the electrical system outside the power-plant section, it was decided to redesign the control system to eliminate chatter that had appeared during vertical tests on the first two rockets. While the phenomenon did not show up during flight, it hampered tests on the ground considerably. In addition, the oxidizer tank, which had been internally contained on the first two rockets, was replaced with an integral tank.

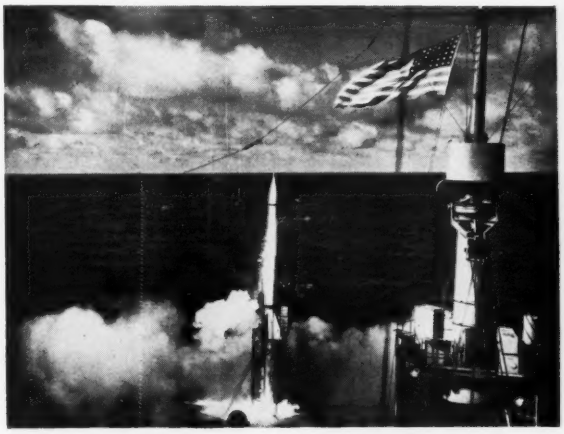

FIG. 4 Viking 4 leaves the deck of the U.S.S. "Norton Sound."

Viking 3 was received at WSPG in January, 1950. Some difficulty was experienced during tests on the control system, and the first attempt at static firing was unsuccessful because of a bad valve in the hydrogen peroxide system. This rocket was launched on February 9, 1950, and at 59.6 sec. was shut down by radio command because of a strong drift to the west. Peak altitude was 50.4 miles. Discussions and analysis of the data obtained from this flight showed the trouble to have been caused by improper operation of the amplifier circuits coupled with a misadjustment of the control system during preflight operations. The decision was made to return to the original amplifier configuration and rely on other revisions remaining in the control system to eliminate the chatter for Viking 4.

Viking 4 arrived at WSPG on March 13, 1950, modified for launching from the deck of the U.S.S. "Norton Sound." The modifications consisted chiefly of structural reinforcement and roller installations on the side of the rocket designed to engage a set of short vertical rails fixed to the deck of the ship. While tests preceding the static firing were being conducted at WSPG, launching equipment was being installed aboard the "Norton Sound," and the adequacy of the launching rails was being tested by a dummy rocket launching. After trouble-free tests at WSPG, Viking 4 was shipped to the West Coast. During tests on board the ship, chatter occurred after encountering trouble from excessive condensation of moisture in the electrical circuits. Efforts to quiet the system were successful, and the rocket, carrying a pay load at over 900 lbs., was launched (Fig. 4) on May 11, 1950, to an altitude of 105 miles above mid-Pacific. This was a record for an American-built single-stage rocket and marked the first successful flight of a rocket of this size and complexity from a naval vessel at sea.

During the interval between Vikings 4 and 5, an intensive program was pursued to eliminate the chatter in the control system. The nature and extent of the phenomenon were sufficiently well established during

* Since the time of presentation of this paper, the difficulties experienced with the sixth rocket have been determined, and resulting design revisions have been made to Viking No. 7. This rocket was launched August 7, 1951, at White Sands Proving Ground to a new record altitude of 135 miles. The flight was considered a success in all respects.

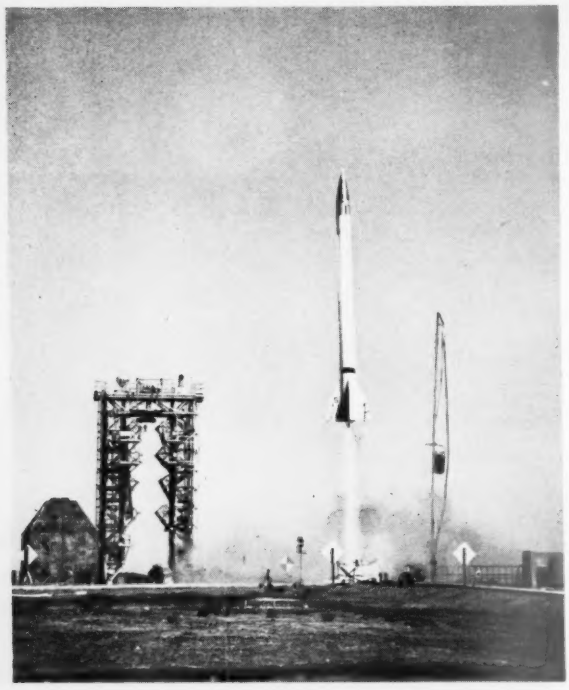

FIG. 5. Viking 5 is launched at White Sands Proving Ground.

the program to permit an effective and repeatable solution to be developed for Viking 5. Hangar and prefiring operations at WSPG with this rocket were accomplished on schedule, including two captive firings accomplished on November 15, 1950. During the morning of November 20, 1950, Viking 5 was launched (Fig. 5) to a new record altitude of 107.5 miles.

Four weeks later on December 11, 1950, Viking 6 was fired. Performance during the first 60 sec. of flight was slightly better than calculated. At this point, a violent maneuver occurred which resulted in a peak altitude of 39 miles. The exact nature of the failure has not yet been determined.

Throughout the operations to date, telemetering equipment has been relied upon to furnish almost all of the needed information on rocket operation during the captive firings, as well as the flights. The equipment was developed and designed by NRL and, by its dependable operation, has established itself as a system of equal importance to the other rocket systems, such as controls and power plant. In addition to providing valuable clues to the causes of failures during flight, the telemeter data show promise of yielding numbers accurate enough to prove out initial design assumptions.

CONCLUSIONS

While the Viking program is not yet complete, the following conclusions can be made based on progress of the program to date.

(1) The basic design of the Viking has been proved to be sound. While the solutions to the initial design problems were not always optimum ones, they have been workable. No failure to date can be attributed to an erroneous initial assumption.

(2) Operation of the rockets in the field shows that the problem of functional design needs to be given full consideration from the start of a design. This concept covers not only the ultimate usability of a component but such other factors as testability, replaceability, adjustability, and accessibility when assembled with other components into a machine.

(3) Telemetering has proved to be an indispensable tool in determination of the causes of our failures and is showing itself to be capable of furnishing data by which design assumptions may be checked.

(4) The philosophy of stopping to correct deficiencies as they arise is a practical one and is considered to be necessary in any development program such as this, where a relatively small number of test articles is involved.

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On the Interaction Between Multiple Jets and an Adjacent Surface

JULIUS JONAS*
Northrop Aircraft, Inc.

SUMMARY

Where single or multiple jets discharge near a surface of an aircraft such as a fuselage, interaction between the jet and the surface will occur. This paper is primarily concerned with the effect related to overheating of a surface near the wake of the jet.

A survey is made of existing theoretical and experimental investigations that, combined with original experimental investigations, point to the general design approach to be taken where such problems exist.

LIST OF SYMBOLS

V_0 = free-stream velocity
V_j = jet pipe exit velocity
t_s = skin temperature, °F.
t_0 = ambient temperature, °F.
t_j = jet pipe exit temperature, °F.
D = jet pipe exit diameter
S = distance between jet center lines
Y = distance of nozzle centerline above surface
α = angularity between jet and surface
P_n = jet pipe total pressure
P_0 = ambient pressure
ϕ = temperature coefficient $= (t_s - t_0)/(t_j - t_0)$

(I) INTRODUCTION

THE ADVENT OF THE TURBOJET ENGINE introduced a number of new installation problems, of which the design of the exhaust system appeared to require particular attention. The interaction between the high-temperature-high-velocity jet issuing from the tailpipe nozzle and any aircraft surface located near its wake became the subject of a number of theoretical and experimental studies. The F-89 Scorpion (Fig. 1) is a typical example where such considerations apply. There were generally two effects to be considered, one concerning the stability and control of the airplane and the other concerning the heat transfer from the jet to any aircraft surface located within its wake. Stability and control were affected by the moment of the thrust forces about the center of gravity, by the incremental downwash induced by the mixing process of the free jet, and by the disturbance of the empennage pressure distribution due to the uneven total pressure field in the wake of the free jet. Tail buffeting as associated with the turbulent structure of the jet boundary became an additional consideration. These problems have been treated experimentally by Falk[1] and theoretically by Ruden[2] and others.

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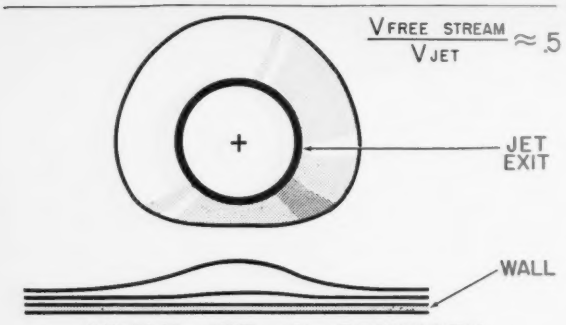
* Supervisor, Thermodynamics Section.

It is the purpose of this paper to discuss the second problem—namely, that concerning the heat transfer from the core or fringes of the jet to any aircraft surface located in its wake. Obviously, for most cases, the provision of stainless steel structure or outright cooling provisions would eliminate this problem as such, although it would not necessarily eliminate possible vibrational failures that might be associated with excessive vicinity to the turbulent boundary of the jet. Since the structural regions involved are generally located aft of the center of gravity, weight penalties and aft c.g. limits appear to discourage such an approach as well. Considering then aluminum structure only, temperature limits of 200° to 250° F. are generally considered as design limits. These temperature limits must be related to a jet exit temperature of approximately 1,300°F. for a nonafterburning jet and some 3,000°F. for an afterburning jet. It is with this background that some general considerations are to be discussed in this paper.

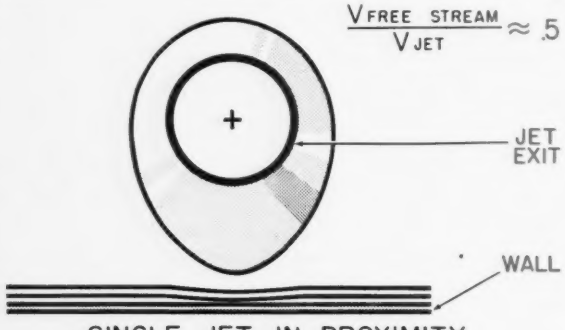
(II) DIMENSIONAL CONSIDERATIONS

For a freely expanding jet, the temperature ratio, as defined by the ratio of the differences of the jet temperature at any given point minus ambient temperature and jet pipe exit temperature minus ambient temperature, is essentially a function of the velocity ratio as defined by the ratio of free-stream to jet pipe exit velocity, the density ratio as defined by the ratio of the free-stream to jet pipe exit density, the jet Reynolds Number, and the nozzle pressure ratio. As the velocity ratio increases from zero to unity, the rate of spread of the jet, which is a measure of the rate of mixing, decreases. A survey of a number of experi-



SINGLE JET IN PROXIMITY OF WALL WITH ADEQUATE PROVISIONS FOR AIR ENTRAINMENT

FIG. 2



SINGLE JET IN PROXIMITY OF WALL WITH INADEQUATE PROVISIONS FOR AIR ENTRAINMENT

FIG. 3

mental and theoretical investigations[3–5] appears to indicate that, although the structure of the turbulence is a function of the absolute magnitude of the velocity, the rate of spread remains essentially constant at a given velocity ratio. Conversely, while the structure of the turbulence varies with a change in density ratio, the rate of spread does not appear to vary significantly with a change in density ratio at a given velocity ratio. That this conclusion applies equally well to the rate of spread of a jet in the proximity of a surface was borne out by tests conducted at Northrop Aircraft, Inc. For a given configuration, the temperature coefficient in the fringes of a jet, as determined by local skin temperatures on the surface adjacent to the jet, was found to be essentially constant for jet pipe exit temperatures varying from approximately 500° to 1,800°F., representing a significant density spread.

The jet Reynolds Number within fairly large ranges appears to have little effect on the temperature coefficient.

Limited data were obtained on the effect of nozzle pressure ratio. In general, temperature coefficients appeared to increase with an increase in pressure ratio beyond the critical pressure ratio immediately downstream of the nozzle, while at larger distances downstream of the nozzle beyond four nozzle diameters, temperature coefficients remained essentially unchanged or slightly decreased up to nozzle pressure ratio's of 3.0. Indications are that the farther downstream from the nozzle a given skin point is located, the larger the supercritical pressure ratio becomes up to which the local temperature coefficient will remain essentially constant. Further experimental evidence proves that, where deflection is imposed on the jet, the degree of deflection will vary with the nozzle pressure ratio beyond supercritical values.

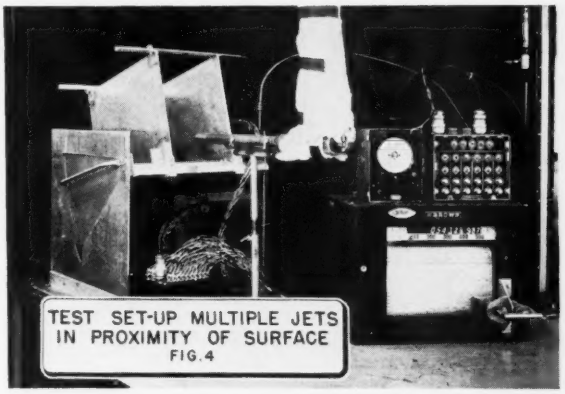
Evaluation of theoretical considerations by Chang[8] and experimental investigation by Küchemann[9] indicate that, where a good aerodynamic fairing is provided between the aft end of a nacelle and an adjacent surface such as to ensure adequate entrainment of free-stream air, the jet pattern evolved near the surface shows little deviation from that of a freely expanding jet. Under static conditions—i.e., for $V_0/V_j = 0$—only a slight shift of the jet wake occurs toward the surface. As the velocity ratio increases above zero (Fig. 2), the jet deforms forming a flat surface while maintaining an essentially conical surface over the portion of the jet circumference facing the free stream. This causes the peak velocities and temperatures to move perceptibly away from the surface, thus reducing the structural heating problem. The surface boundary layer appears to experience only an insignificant modification by the presence of the jet.

Where inadequate entrainment of free-stream air is provided between the surface and the jet due to the particular aerodynamic configuration, the jet may only slightly deflect toward the surface at $V_0/V_j = 0$. However, for larger values of V_0/V_j (Fig. 3), the jet is deformed in such a manner as to assume a quasi-elliptical cross section with the major axis normal to the fixed surface. This in effect deflects the jet significantly toward the surface. Similar indications were observed by Bäuerle[10] on a single pod installation beneath the fuselage of a Heinkel 219 in wind-tunnel tests conducted at Göttingen. With a configuration of the jet centerline spacing beneath the surface $Y/D = 1.514$ and a blunt aft fairing between the nacelle and the fuselage, a perceptible deflection of the jet toward the fuselage surface occurred at a velocity ratio of $V_0/V_j = 0.5$. With a configuration of $Y/D = 1.950$ and with what might be termed a good aerodynamic fairing between the nacelle and the fuselage, the jet actually slightly deflected away from the surface at a velocity ratio of $V_0/V_j = 0.5$.

(III) Experimental Investigations on the Behavior of Multiple Jets in the Proximity of a Surface

To secure more general and fundamental data, tests were conducted by the author disregarding all special wall forms to secure information on the jet behavior of multiple jets in the proximity of a surface. Initial tests were conducted discharging the jets into still ambient air.

The apparatus (Fig. 4) consisted of a source of hot air of approximately 500°F. discharging through a 1.00-in. i.d. cylindrical nozzle. Provisions were made to adjust the vertical position of the nozzle above the surface, as well as the angularity between the jet axis and the surface. Two vertical surfaces were provided with adjustable lateral positioning. Each surface represented a plane of symmetry between the central jet and a left-hand and right-hand jet, thus simulating a second and a third jet. Thermocouples were imbedded in the horizontal surface along the centerline of the central jet, as well as on the vertical surface at the intersection of the horizontal and vertical plane (Fig. 5). These thermocouples were insulated from the surface plate by imbedding them in a bed of sauereisen permitting only the hot junction of the thermocouple to be exposed to convective heat transfer from the jet fringes. Thus scale effects appeared to be minimized. Ambient and tailpipe jet temperature thermocouples were provided. All thermocouples were connected to a Brown Recorder, permitting rapid recording of the temperatures. Tailpipe total pressure was measured for the determination of the reference nozzle pressure ratio.



TEST SET-UP MULTIPLE JETS IN PROXIMITY OF SURFACE
FIG.4

THERMOCOUPLE INSTALLATION MULTIPLE JET TEST
FIG.5

Initial tests were conducted to evolve the test technique required to eliminate and correct for secondary heat-transfer effects. There were two effects to be considered. The first effect related to the convective heat transfer into the side plate as affecting the drop off in jet temperature as compared to the case of the jet bordering an actual jet. This effect was minimized by maintaining high jet velocities, thus giving small temperature drops due to convective losses.

The second effect related to secondary conductive and radiant heat transfer into the thermocouples, thus affecting the readings that were primarily intended to be related to the convective heat transfer by the jet. This effect was minimized by the use of imbedded thermocouples and by further checking maximum skin temperatures with a shielded thermocouple probe. Fig. 6 shows the geometric parameters used in this investigation.

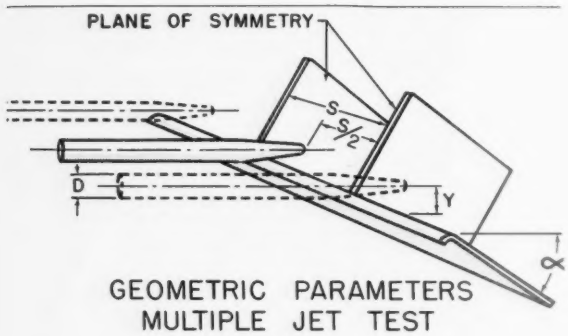
Fig. 7 shows the results obtained for single, twin, and triple jets giving maximum surface-temperature coefficients as a function of jet spacing above the surface Y/D. Spacing between jets for the case of twin and triple jets was maintained constant at $S/D = 1.50$. Jet angularity α and velocity ratio V_0/V_j were maintained at zero. The nozzle pressure ratio was kept constant at $P_n/P_0 = 1.650$. As can be readily inferred from Fig. 7, an increasing congestion of jet gases occurs in the proximity of the base surface as the number of jets is increased from one to two and three. The peak temperature coefficient as shown is actually associated with different locations as the jet spacing is varied. The peak point moves gradually forward as Y/D is decreased. In general, at low values of Y/D, peak temperatures remain constant for several nozzle diameters indicating local fringe attachment. For a single jet, peak temperatures occur on the surface line at a minimum distance from the jet centerline. For twin and triple jets, peak temperatures occurred, in general, along the intersection of the plane of symmetry and the base surface.

Fig. 8 shows the results obtained for single, twin, and triple jets giving maximum surface temperature coefficients as a function of the jet angularity α. Spacing between jets for the case of twin and triple jets was maintained constant at 1.50. The jet spacing above the surface was kept constant at $Y/D = 0.750$. The jet velocity ratio V_0/V_j was kept at zero, and the nozzle pressure ratio was kept at $P_n/P_0 = 1.650$. A similar relationship between single, twin, and triple jets is apparent as was the case where the jet spacing Y/D was varied, except that, in the case of the triple jet, a

significant degree of jet deflection was accomplished for approximately 25°, which might be termed a classical example of the Coanda effect, where a jet is deflected through prevention of air entrainment over a portion of the jet circumference.

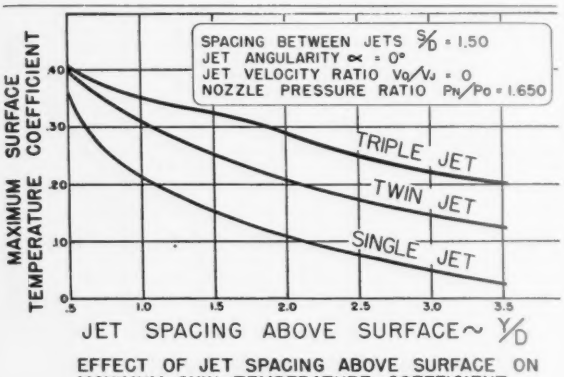
It is of interest to note that Kunze,[11] in water canal tests of jets issuing obliquely from a surface, concluded that a single jet clears an adjacent surface when inclined to it by more than 12°, which checks fairly well with the data given in Fig. 8.

It is of further interest to note that twin jet data shown on Fig. 8 follow essentially the same pattern as experienced on model and full-scale tests of the F-89 Scorpion.



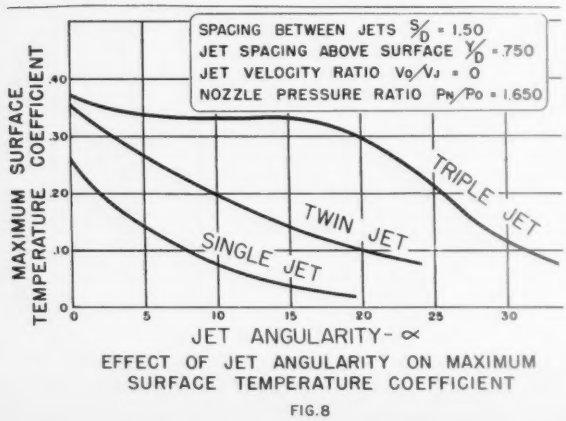
GEOMETRIC PARAMETERS
MULTIPLE JET TEST

FIG. 6



EFFECT OF JET SPACING ABOVE SURFACE ON MAXIMUM SKIN TEMPERATURE COEFFICIENT

FIG. 7



EFFECT OF JET ANGULARITY ON MAXIMUM SURFACE TEMPERATURE COEFFICIENT

FIG. 8

In addition to the basic geometric parameters additional parameters were considered.

(1) *Nozzle Configuration*

During tests of a single jet discharging in the proximity of a surface, it was observed that, while maintaining all other parameters constant, changing the nozzle slope from 9° to 15° resulted in an increase of the maximum skin temperature coefficient by approximately 0.075, thus indicating the importance of this parameter.

(2) *Ejector Configuration*

During tests of a single jet discharging in the proximity of a surface, it was observed that, while maintaining all other parameters constant, changing the ratio of the ejector shroud exit diameter to nozzle diameter from 1.05 to 1.15 increased the maximum temperature coefficient by approximately 0.075. While these values are merely intended to be of a qualitative nature only, they point to the need for careful detail design.

(3) *History of the Boundary Layer and General Free-Stream Flow Field Approaching the Jet Wake*

Wind-tunnel tests by Bäuerle and Küchemann[9, 10] clearly point to the importance of evaluating the general flow field within which the jet discharges as it affects the air entrainment by the jet and thus the behavior of the jet in relation to the surface.

(IV) Jet Behavior in the Proximity of the Fuselage of the F-89A Scorpion

The F-89A airplane (Fig. 9) is a twin-engined fighter powered by two afterburning jet engines mounted under the wing within the fuselage. The afterburner is surrounded by a shroud that extends past the nozzle, thus forming an ejector. The shroud is in effect extended past its own exit in the region close to the fuselage, thus separating the jet from the adjacent structure and forming a jet deflection control surface. Downstream of this surface the fuselage gradually pulls away from the jet axis. Because of the vicinity of the jets to the surface, there was a potential problem of fuselage overheating. Because the jets were also located close to each other, the surface temperatures appeared to be susceptible to even larger values due to the combined effect of the twin jets. Reviewing the general discussion presented in this paper it could have been inferred that the configuration of the F-89 Scorpion fell on the border line between the case where maximum skin-temperature coefficients are associated with minimum values of the velocity ratio V_0/V_j and the case where maximum skin-temperature coefficients are associated with maximum values of the velocity ratio V_0/V_j. In the first case, the ground condition would be critical with the attendant simpler means of conducting model and full-scale tests. In the second case, flight

conditions would be more critical, thus rendering the test program somewhat more complex.

Extensive model and full-scale ground tests were conducted under still air conditions evolving a jet deflection control surface configuration to keep the maximum fuselage temperature essentially below 250°F. This corresponds to a temperature coefficient of about 0.050 for a jet temperature of 3,000°F. on a hot day.

The jet deflection control surface appeared to incorporate sufficient flexibility in terms of jet deflection and transport of entrainment air into the critical aft regions between the jets and the fuselage that wind-tunnel tests were omitted in favor of actual flight tests.

Initial flight tests showed maximum fuselage temperatures of approximately 425°F. at low altitude high-speed afterburning conditions. Thus, the maximum skin-temperature coefficient appeared to be approximately doubled from 0.050 to 0.10. However, it was found possible, through slight adjustments of the jet deflection control surface which permitted additional transport of free-stream air into the critical region, to lower the maximum fuselage temperatures again below 250°F. It is significant to note that this temperature change should not be associated with an incremental jet deflection but rather with a change in the type of jet deformation as shown by Küchemann[9] (see Figs. 2 and 3). It is felt that this latter concept leads to a better understanding of the problem and the engineering approach required for its solution.

It may be noted that, by arriving at a final configuration of the jet deflection control surface, due consideration was given as to its effect on ejector performance with particular reference to shroud exit chocking and attendant internal jet reversal under high Mach Number—high nozzle pressure ratio conditions.

(V) Conclusions

While sufficient evidence has not been presented, it nevertheless is apparent that there is a parametric boundary defined by geometric, aerodynamic, and jet parameters. On one side of this boundary, maximum surface temperature coefficients are associated with minimum values of the velocity ratio V_0/V_j—that is, with ground conditions. On the other side of this parametric boundary, maximum skin-temperature coefficients are associated with maximum values of the velocity ratio V_0/V_j—that is, with low-altitude, hot day, high-speed conditions.

Exploratory tests are necessary at an early stage of a design to establish the relationship of it to this parametric boundary, as well as to the maximum temperature coefficient under static conditions.

Data presented in this paper may be of assistance in qualitatively judging initial design concepts, particularly where accompanied by exploratory tests of a nature indicated in this paper.

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Engineers for the USAF

by

Major Robert R. Lent*

THERE IS A NATION-WIDE SHORTAGE of approximately 40,000 engineers of all kinds—electrical, mechanical, chemical, aeronautical, etc.—and there is no prospect that the output of our engineering and technical schools will suffice even to prevent the ratio between supply and demand from becoming more unfavorable.

In the light of this fact, the recent program of the Air Force's Research and Development Command, designed to ensure maximum benefit from the services of 600 carefully chosen new officers with technical training, assumes an important role in the national effort to ameliorate the effects of the shortage.

ARDC, newest of the Air Force's major commands, was established less than a year ago to conduct and supervise all the research and development activities necessary to assure that continuing flow of new planes, weapons, and equipment which is so essential to our national security. Soon after ARDC's activation, it became apparent that one of the first and most pressing problems was to find the right kind of technically trained personnel.

A certain amount of work could be done, and was done, within the Air Force by "salvaging" officers with high research and development capabilities who had been assigned to duties that did not require the full use of their highest capabilities. This gain, however, hardly sufficed to replace those officers who, because of inadequate classification procedures, had been participating in the Research and Development program without possessing the minimum qualifications to perform their duties in a satisfactory manner.

A most important and highly welcome source of engineering talent was opened early in 1951 by the decision of the Secretary of Defense that all ROTC students graduating in the spring of 1951 would enter on active duty. Well before graduation, plans were made for the fullest utilization of the students most suitable for research and development work. In this planning, the Deputy Chief of Staff, Development at Headquarters, USAF, cooperated with the Command-

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2nd Lieutenants who recently entered the six-week program of orientation at USAFIT, prior to duty of assignment within the new Air Research and Development Command, listen to Brig. Gen. Gilbert Hayden, Deputy Commanding General of the Wright Air Development Center, tell them that they have been carefully selected on the basis of technical capacity and engineering talent and that they represent the cream of the crop in brains.

ing General of ARDC and the Wright Air Development Center at Wright-Patterson Air Focre Base, Dayton, Ohio.

Surveys were made to determine the number of ROTC graduates which could be profitably utilized in Air Force research and development activities. In order to obtain the top-notch men of their class, department heads and professors in the nation's engineering schools were asked to submit names and pertinent data on the top ten per cent of their senior ROTC students.

Thanks to the whole-hearted cooperation of these educators, the Deputy Chief of Staff, Development, soon had a listing of about 800 candidates for assignment to ARDC. Information was supplied on the academic courses, class standing, primary interest, potential capabilities, characteristics, and personality of each student.

The technical qualifications and research and development potentialities of these 800 were then matched against the predetermined need. Finally, 600 of the group were selected, and the Deputy Chief of Staff, Personnel, was requested to assign them, by name, to ARDC.

This action, however, was merely the end of the beginning. Now it was necessary to make sure that each of these hand-picked young lieutenants was placed where he could utilize his engineering training to the fullest possible extent. The objective was to obtain maximum efficiency from the new engineering personnel, thus: (1) decreasing the quantitative demand and making minimum inroads upon the supply of engineering talent required by private industry, and (2) holding research and development personnel costs to the lowest possible level consistent with a balanced research and development program.

To meet this objective, a unique five-week program was inaugurated at Wright-Patterson Air Force Base. Here, not only did these young officers learn about the Air Force; the Air Force also learned about them.

(*Right to left*), Lt. Gen. Earle E. Partridge, Commanding General, Air Research and Development Command, Major Gen. Fred R. Dent, Commanding General, Wright Air Development Center, discuss the operation of the school prior to graduation ceremonies with the school's originator, Col. Perry M. Hoisington, Director of Personnel for Air Research and Development Command.

The 600 were to be spread throughout the ARDC, many of them as assistant project engineers. It was essential that each understand how his particular job fitted into the overall picture. Each had to be impressed with the manner in which aerodynamics, thermodynamics, propulsion, electronics, chemistry—all the engineering specialties—are fused in the development of a complete weapons system. To demonstrate this, the evolution of a complete weapons system was traced from drafting board to model prototype. Through illustrations by project engineers of pitfalls incident to the creation of actual weapons, the vital and challenging aspects of research and development work were brought home.

The host of problems that confront the development engineer were presented by military and civilian lecturers. A ceramics engineer discussed the application

(*Left*), Instructor, Air Force Institute of Technology, demonstrates functions of hydraulic propellers with a mock-up installation for Air Force ROTC lieutenants, Wright-Patterson Air Force Base, Dayton, Ohio. (*Right*), Young lieutenants of the Air Force ROTC program enter a B-26 demonstration aircraft at Wright-Patterson Air Force Base, Dayton, Ohio.

of his art to the problems arising out of the terrific heat generated by jet engines. Aeronautical and mechanical engineers explained the complexities of instrumentation. Chemical engineers elaborated on the necessity of keeping critical parts working, despite the effects of salt spray, sand, heat, or cold.

Then, aeronautical engineers indicated the nature of the compromises they must make in order to accommodate their designs to the requirements of an effective weapons system. On every hand, the young engineers heard the admonition to be constantly aware of the interdependence of the manifold activities that produce fighting planes. They frequently visited the aeronautical, armament, power-plant, equipment, and aero-medical laboratories.

The student officers also previewed Air Force accomplishments in various fields. They learned how high, how far, how fast, and with what accuracy our new guided missiles will go. They saw models of missiles and classified films on their operation. They absorbed the same information respecting new bombers, interceptors, troop carriers, and helicopters.

In addition to lectures and demonstrations designed to show the techniques, problems, and accomplishments of the project engineer, time was devoted to nontechnical subjects. Of paramount concern was the preparation of oral and written reports and the handling of personnel problems. Emphasis was also placed on management principles and techniques of organization. The duties of the project engineering officer will require not only technical competence, but administrative skill and the ability to stimulate cooperative enterprise as well. Admittedly, all this cannot be learned through lectures; for experience remains the best teacher. But it is possible to construct a frame of reference upon which experience and subsequent training can build.

Concurrently with the operation of the school, the new officers' duty assignments were determined. Each officer went before a placement panel that recommended assignment on the basis of Air Force needs and the officer's training, inclination, and geographical preference.

Take the case of Ronald Nelson, a 1951 honor graduate of a leading midwestern university. Lieutenant Nelson received his degree in electrical engineering. Consequently, when his turn came to be interviewed, he went to Panel 5, where the requirements for persons with electrical engineering training were assembled. The panel contained representatives from Holloman Air Force Base, N. M.; Patrick Air Force Base, Cocoa, Fla.; Rome Air Force Base, New York; Edwards Air Force Base, Muroc, Calif.; Eglin Air Force Base, Fla.; and Air Research and Development Command, Baltimore, Md. For about half an hour, Lieutenant Nelson was asked questions and given the opportunity to ask questions in return. He indicated that he wished to work on electric computers, if possible. The experts in this field discussed the opportunities and the current state of the art.

After Lieutenant Nelson left, the panel compared his qualifications with the requirements at the various bases. Since he had expressed a preference for Patrick Air Force Base and a requirement existed at that base for his specialty, he was recommended for assignment there.

Over 600 of his fellow officers went through a similar procedure and received the same careful consideration.

During the coming months these young men will be striving to help make the United States Air Force the finest in the world. At missile test centers and engineering laboratories, they will serve our Nation's interest in providing for the Air Force of the future.

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Aircraft Nuclear Propulsion*

M. C. LEVERETT†

ANP Project, General Electric Company

(1) Introduction

A DISCUSSION OF THE INTERESTING SUBJECT of propulsion of aircraft by nuclear power is unfortunately considerably restricted by Security. My task in making this talk is, therefore, not an easy one, and if I omit to say exactly how some of the interesting problems that I shall tell you about may be solved, it will be understood that this is unwise at present. There is, of course, the chance that in following this line I shall be credited with knowing the answers to many more problems than actually have been solved, and I hope that, should you later discover that we who are working in this field have made more or less progress than you assume from my present remarks, you will not feel that I have intentionally misled you.

"In spite of the restrictions placed upon our discussion, we can discuss in fairly free fashion the principles underlying nuclear powered flight, some possible methods of achieving it, and some problems that are involved. Before starting this discussion, however, we should pause a moment to answer the question, 'Why do we want to fly an aircraft on nuclear power?'

"Many years ago, Breguet set down the formula that bears his name and which states that the range of an aircraft is proportional to its lift-to-drag ratio, to the efficiency with which its propulsive system works, and inversely proportional to the weight of fuel consumed per unit of work delivered to the propulsive system. Any decrease in the specific fuel consumption obviously leads to increased range. Because of the ingenuity of the designers of aircraft and engines, the Breguet formula is scarcely of more than academic interest in these days. Devices such as accomplishing most of a flight slowly and using high speed only at critical times, refueling in flight, and discarding not only the fuel tanks but also the lifting surfaces that support them as soon as they are empty—all have been seriously proposed or practiced and operate greatly to increase the range of modern aircraft. However, it is no deprecation of our heavy bombers, which are the best in the world, to say that even more range would be desirable, particularly if it can be coupled with high speed. This is the point at which the nuclear-propelled airplane comes into the picture. One pound of uranium-235 will liberate heat on undergoing fission equivalent to the energy liberated by burning 1,700,000 lbs. of gasoline. It is at once evident that, if a means can be found for converting the energy of nuclear fission into thrust, aircraft can fly for very long times on very small amounts of fuel. Indeed, fuel consumption would be measured not in thousands of pounds per hour, but in pounds per day. Because of the enormous amounts of energy available from a small amount of fuel, highly efficient utilization of this energy would no longer be crucially important. Thus, specific fuel consumption could be allowed to worsen somewhat if this were desirable in order to make some other feature of the power plant easier or better.

"Although the basic superiority of nuclear fuel over chemical fuel is thus superficially stated as a simple ratio of 1.7 million to 1, the implications and complications of this fact are extremely varied and far reaching. For example, some of the implications may be listed. A nuclear aircraft could encircle the globe many times without stopping, although this particular maneuver would be more dramatic than useful. It could fly entirely around the world at local midnight, accomplishing the entire circuit in darkness and with the lower vulnerability that night flying confers. Careful husbanding of fuel, programing of flight speed and altitude, and closely timed flight plans would become unnecessary in a nuclear-powered airplane. Such an airplane could fly at its maximum speed and at any altitude over its operating range for all or any part of its mission and still be perfectly sure of having enough fuel to return to its home base by any route whatever. A nuclear-powered aircraft could possibly stay aloft for many days. It would be limited only by the freedom

* A talk given October 4 before the Chicago Section of the Institute of the Aeronautical Sciences.

† ANP Project, Oak Ridge, Tenn.

of the aircraft and power plant from breakdown and by the ability of the crew to endure long hours of flight and exposure to nuclear radiation. It is clear that many missions that are impossible for chemical aircraft would be possible with nuclear-powered aircraft.

(2) Principles and Suggested Methods

"One of the basic principles of nuclear energy is that the energy of fission is manifested as heat. That is, a nuclear reactor is primarily a source of heat that must be converted into thrust or into mechanical work in more or less conventional ways. Hence, in any nuclear power plant, whether it is for an aircraft, a naval vessel, or for the generation of electricity on the ground, there will be a reactor and heat machinery. In the aircraft, the heat machinery is the propulsion system. Secondarily, and somewhat unpleasantly, the reactor is a source of radioactivity; hence, there will also be a shield of some type or other.

Propulsion Machinery

"There is scarcely a single type of aircraft propulsion machinery which has not been proposed for incorporation in a nuclear power plant for aircraft. One obvious proposal is that propellers be used, driven by turbines that are in turn run by expanding through them vapor such as steam, heated in the reactor or air heated in the reactor. A variation of this scheme would be to extract the heat from the reactor by some liquid coolant rather than vapor or air and transfer it to the vapor or air in an external heat exchanger or boiler. Another fairly obvious proposal is that the reactor should directly or indirectly take the place of the combustion chambers of a conventional turbojet engine. Here again, the heat might be extracted from the reactor directly by the air or indirectly by other coolants, such as liquid metals, and transferred to the air outside the reactor. Ducted fans driven by turbines, operated in turn by vapor or air heated in the reactor, have been suggested. Obviously, the reactor might also take the place of the combustion apparatus in a ram-jet propulsion system. It has also been proposed that a compressor-jet type of propulsion system be used, with the compressor driven by vapor or hot air from the reactor and the heat supplied to the air by a heat exchanger through which the reactor coolant passes. In all cases, except that of the ram-jet and other direct air cycles, it is required that heat be transported in a recirculated coolant from the reactor to the propulsion machinery. In making a choice among the various types of propulsion machinery which have been suggested, the designer must perform detailed and careful analyses of many different possible combinations. Some of the problems that confront him are so obvious that they may be mentioned here. For example, if a propeller-type propulsion system is chosen, the hot fluid from the reactor must be piped to the turbines that drive the propellers; these in turn must be mounted on the wings. Thus, each propeller must be provided with its own reactor, or hot fluids must be piped around the airplane from a central reactor heat source. Any reactor coolant will undoubtedly become somewhat radioactive in passing through the reactor, and, hence, this alternative is not attractive. On the other hand, providing each propeller with its own reactor is not easy either, for two reasons. First, the weight of a reactor, with its shield, is extremely large; more than one reactor and shield therefore is highly undesirable from a weight standpoint. Second, two reactors per airplane would require more than twice the fuel investment of one reactor, and a low fuel investment per airplane is desirable, rather than a high one.

Reactor

"The design of the reactor will be greatly influenced by the coolant chosen. However, the basic principle upon which the reactor operates is the same regardless of the coolant. This principle is as follows: The reactor may be thought of as a more or less cylindrical body throughout which a fissionable material, such as uranium-235 or plutonium-239, is distributed. The reactor also contains passages for the flow of the coolant through it necessary for the removal of the heat and also usually contains a material that is called a *moderator*. The reaction starts with the capture of a neutron by a nucleus of, say, uranium-235. Since neutrons are present in small concentration in the atmosphere everywhere, this serves to start the reaction. Immediately after capture of the neutron, the U-235 nucleus disintegrates with the liberation of 2 to 3 neutrons and 2 atomic nuclei (fission fragments) both smaller than the original nucleus. Most of the energy of fission is carried off by the fission fragments; this energy is imparted to the material into which they are cast and appears as heat. Gamma rays and beta rays also are given off in the fission process.

"The 2 to 3 neutrons given off are ejected into the body of the reactor and may undergo one of three different fates. (1) They may escape from the reactor entirely and be captured outside it by some parasitic nucleus in the structure of the shield or its surroundings. (2) They may be captured by some of the nonfissionable materials in the reactor itself. (3) They may be captured in another U-235 nucleus, following which 2 to 3 additional neutrons will be given off. If we can design the reactor so that about 40 per cent of the neutrons given off in fission are captured in other fissionable nuclei in such a way as to cause fission there, the reaction will continue indefinitely until the fissionable nuclei are used up.

"The basic problem of reactor design is to reduce to acceptably low values the first two methods of loss of neutrons mentioned above—that is, leakage from, and parasitic capture in, the reactor. Leakage may be counteracted to some extent by surrounding the reactor with a neutron reflecting material that scatters but does not capture the neutrons. For example, graphite and beryllium oxide are known to be good reflectors.

Excessive capture of neutrons in nonfissioning nuclei in the reactor may be avoided by eliminating from the reactor atomic species that have a strong tendency to capture neutrons or, in the language of the nuclear physicist, have a high neutron capture cross section. Unfortunately, it is not always easy to do this because some of the materials that are most suitable for use as reactor structure, and without which the reactor will not support itself, have rather high capture cross sections. These are thus poisons for the nuclear chain reaction although essential for the mechanical stability of the reactor. Obviously, we may increase the fraction of the neutrons that are absorbed in U-235 or Pu-239 nuclei by increasing the proportion of U-235 or Pu-239 present in the reactor. Unfortunately, this increases the amount of fissionable material invested in the reactor, and, since fissionable material is extremely precious, it is desirable to keep its investment to a low value. We usually, therefore, resort to the device of introducing into the reactor a *moderator*. A *moderator* is an element of low atomic weight and low capture cross section for neutrons. Because of its low atomic weight, a neutron striking it loses a relatively large fraction of its energy in each such collision. Because of its low capture cross section, it does not capture many of the neutrons that strike it. After the neutrons are thus slowed down or moderated, their capture by the fissionable material in the reactor becomes much more probable since the cross section for capture of low energy neutrons is higher than that for high energy neutrons. Typical moderators are graphite, ordinary water, heavy water, beryllium, and beryllium oxide.

"The control of the chain reaction is, in principle, exceedingly simple. One of the most direct means of control is to arrange an absorbing rod so that it can be inserted into the reactor or withdrawn from it. If the rod is withdrawn from the reactor, it will absorb a smaller number of neutrons than before. If, in its original position, the rod was absorbing that number of neutrons which made the reactor just critical (that is, neither rising nor falling in power), then withdrawal of the rods will create a slight excess of neutrons in the reactor and the power will begin to increase. If, for example, we withdraw the rod so that the fraction of the neutrons absorbed in fission is 0.1 per cent greater than before, then the number of neutrons in the reactor will increase by 0.1 per cent in each neutron generation. Since the neutron generation time is extremely short, the reactor will build up fairly rapidly in power in an exponential manner. When it is desired to stop this build-up, all that is necessary is to insert the control rod to its original position. This will deprive the neutron cycle of its 0.1 per cent excess, and the power of the reactor will stay steady at the new level thus reached. Similarly, if it is desired to decrease the power of the reactor, inserting the rod more deeply than its original position will enable it to absorb more neutrons than before, and the chain reaction will gradually die. Other methods of control have been proposed also. For example, in a reactor which has a reflector, removal of part of the reflector will allow the leakage of more neutrons than before. This will decrease the reactivity and constitutes a method of control. Also, removal of part of the moderator or of some of the fuel itself from the reactor will decrease the reactivity, and these expedients may also be used as control mechanisms.

"It is evident that the control of the reactor is an important matter; not so much because of the very remote possibility that the reactor might turn itself into a low-grade atomic bomb, but because, if the power of the reactor fluctuates without a corresponding fluctuation in the heat removal capacity of the heat-transfer system, the reactor inevitably will heat up. Overheating, if sufficiently severe, can cause accelerated corrosion, warping, or even melting of parts of the reactor. Evidently, too, it is important that the reactor not be operated without a flow of coolant through it, since this certainly will result in serious damage if not destruction of the reactor.

Shield

"Although most of the energy of nuclear fission appears as kinetic energy of the two fission fragments mentioned above and this kinetic energy in turn appears as heat in the fuel elements, a substantial portion of the energy of a reactor appears as kinetic energy of the neutrons and as ionizing radiation, such as gamma rays and beta rays. The neutrons and gamma rays, if allowed to escape with complete freedom from the reactor, would make it necessary for human beings to stay at a distance of more than a mile from a high-powered reactor while in operation. Moreover, since the fission products themselves are radioactive and continue to emit gamma rays even after the chain reaction has been stopped, it would not be possible to approach the reactor much closer than this even after it had been shut down. It is clear that a *shield* must be provided.

"The basic requirements of the shield are dictated by the two basic types of radiation which it is desired to stop. The neutrons are slowed down most effectively by light atoms such as hydrogen and, moreover, are more easily captured after being slowed down. For this reason, an effective shield will contain light atoms such as hydrogen, which also is a good slow neutron absorber. Gamma rays, on the other hand, are degraded in energy and stopped best by heavy elements, such as lead. Hence, the shield normally will contain heavy elements also. It is clear that a mixture of light and heavy elements arranged in the most strategic fashion will be desired. The details of this arrangement are not particularly important for a large stationary reactor such as those that have been built on the ground in the past. However, for a reactor that is to be mobile, it is important that the shield weight and dimensions be kept small. Hence, the materials put into the shield must be the best possible and must be arranged in the best

possible fashion. The detailed solution of this problem is extremely complicated.

"Another point of importance is that not only must the shield prevent escape of radiation from the reactor to the desired degree but also it must be capable of admitting and emitting the coolant that carries the heat away from the reactor. This means that the ducts must pierce the shield, and we are then confronted with the problem of leakage of radiation through these ducts. Generally speaking, gamma rays and neutrons travel in straight lines. However, under certain conditions, they can be scattered or reflected around corners or curves. This confronts us with another difficult but interesting problem in the shield.

(3) Some Problems of Nuclear-Powered Aircraft

"It may be interesting to pose some difficult problems, in addition to those mentioned above, which confront the designer of a nuclear-powered aircraft.

Shield Weight

"The shield will be the heaviest single object aboard the aircraft. Early published estimates of shield weight placed the minimum shield at 50 to 100 tons, without any provisions for removal of heat. From this it is evident that a large aircraft will be required to carry a weight of this magnitude even though the aircraft need carry little or no chemical fuel. To a first approximation, one may balance off the weight of the shield against the weight of the fuel load that would be carried in a large modern aircraft, since the shield and the reactor that it contains essentially replace the fuel load. The fuel loads of modern aircraft range up to the neighborhood of 75 tons or more. If the early estimates of shield weight referred to above are anywhere near correct, it is evident that the weight of the shield plus the reactor is not grossly different than that of the fuel that can be carried in a large conventional aircraft. However, every effort must be made to keep down the weight of the shield and the reactor. One obvious way to do this is to make the reactor small so that the shielded volume is kept small. This in turn restricts the amount of cross-sectional free flow area through which the coolant may pass through the reactor and increases the pressure drop. Moreover, as the reactor diameter decreases, it usually is found that more fissionable material is required. This is undesirable. There is therefore a balance to be struck between the benefits of small shield weights resulting from decreased reactor size on the one hand and the disadvantages resulting therefrom in smaller free flow area for coolant flow and larger fissionable material investment required.

Balance and Structure

"The existence of a larger concentrated weight, such as the shield and the reactor at one point in an aircraft, makes it necessary to redesign the structure of the aircraft to accommodate this weight. Although large aircraft are designed for very large gross weights, this weight is usually distributed over the wing and throughout the fuselage. Concentrating the weight in the fuselage greatly increases wing bending moments and necessitates structural redesign in many cases.

Large Landing Weight

"The very fact that only a small amount of the fuel is consumed in flight means that the gross weight of a nuclear aircraft will be approximately the same on landing as on take-off. This gives rise to a possibly serious set of new problems. First, the landing gear must be made strong enough to take the higher gross landing weight. Second, the landing speed is increased, and there may be a change in landing attitude which possibly could require changes in the landing gear or in tail clearance angle requirements.

Heat Transfer

"The very essence of a nuclear power plant is the transfer of heat from the reactor to the propulsion machinery. The requirements for small size and high-power density placed upon the aircraft reactor push the heat-transfer designer to the limit of his knowledge. He must avoid hot spots in the flow system, he must have good flow distribution, and he must know exactly how the power is distributed in the reactor so that he can supply the right amount of coolant to each part of it. Solution of these problems requires a great deal of detailed analysis and experiment. For example, consider the cooling of a surface beneath which nuclear fuel is located in a reactor. The rate of heat generation is independent of the local temperature; thus, if the surface be deprived of its coolant, it will at once rise in temperature until it melts or disintegrates. The reactor is like a heat exchanger to which heat is constantly supplied whether it is taken away or not; only by maintaining the flow of coolant can trouble be avoided. Reactors in which the fuel is in solution in the coolant have been suggested for avoiding such problems.

Fissionable Material Investment

"The desirability of keeping the quantity of fissionable material in the reactor small has been mentioned previously. It is obvious that this is desirable. However, the chain reaction will go in the reactor only so long as there is present a certain minimum quantity of fissionable material called the *critical mass*. As soon as the reaction has consumed so much fissionable material that the mass drops very slightly below the critical mass, the chain reaction dies and cannot be started again without adding more fissionable material. Moreover, the products of fission remain in place in the fuel elements and eventually must be removed. This makes it necessary to remove the remaining fuel from the reactor, purify it, and prepare it for reuse. The amount of uranium which may be tied up in the reprocessing activities may easily exceed that which is tied up in the reactor proper. Thus, the uranium investment is not

simply the amount of uranium carried aboard the aircraft but also that which is on the ground in various stages of preparation for use. The question of recovery and reprocessing of the fissionable material is a matter for the chemist and chemical engineer and is a whole new subject on which I shall not touch further here.

Radiation Damage

"Internuclear collision between neutrons and the nuclei of materials used as structures or as moderators in the reactor or between fission fragments and other nuclei results in dislocation of the nuclei with which collision occurs. While it is not definitely known how great an effect these dislocations have, it is known that the properties of the materials in which they have occurred undergo a change. Usually this change is in a detrimental direction. For example, a decrease in thermal conductivity may occur, thus making the heat removal problem even harder. Or, other equally critical properties may deteriorate.

"Some liquids or gases that might be proposed as reactor coolants are decomposed by radiation and are, hence, not usable. Organic compounds are particularly susceptible, and, even outside the zone of most intense radiation in the reactor, ordinary lubricants turn tarry or even solidify. Lubricated machinery hence may not be used in such locations. Electrical insulation, on prolonged exposure to radiation, breaks down and disintegrates or loses its effectiveness.

"There is here a large field of investigation, particularly in the physics of solids, where much work must be done in order to elucidate the effects of radiation damage, as this phenomenon is called, on the materials that might be used in an aircraft reactor or in radiation-exposed locations in the shield.

Escape of Radioactivity

"It is evidently necessary to confine substantially all the radioactivity of the reactor within it. This imposes on the designer of the reactor another restriction. It is occasionally suggested that a nuclear aircraft will create a hazard to population in its vicinity. Inasmuch as the aircraft itself will carry a crew which must be protected adequately, persons at a distance will not be affected in any way.

Materials

"One of the most important problems in reactor technology today is the finding and development of materials adequate for use in reactors that are proposed for production of power in one form or another. The combined effects of high temperature, corrosion by various coolants, radiation damage, thermal stresses, and mechanical stresses can be extremely serious in some cases. The aircraft reactor presents these problems to an unusual and critical degree. For example, a difference of 100°F. in permissible maximum reactor temperature can easily produce a significant difference in thrust output of the power plant. High-temperature materials are therefore a prime necessity. A corrosion-resistant coating on the reactor heat-transfer surfaces a few thousandths of an inch thick may double the critical mass. A brazing alloy containing a few per cent boron (a strong neutron absorber) may put so much boron into the reactor that it cannot be made to go critical, and this particular alloy may therefore be entirely unusable. An alloy high in nickel may have good corrosion and high-temperature strength properties for use as reactor structure but be so strong a neutron absorber as to be substituted by another alloy of lower nickel content and poorer corrosion and strength properties. The finding of materials adequate to withstand these conditions is a challenge worthy of the best metallurgist, ceramist, or chemist.

(4) Outlook

"In many respects, the propulsion of aircraft is an ideal use for nuclear energy. Here, to a higher extent than in any other application, the advantages of a highly concentrated source of heat can be used to good result. Although the goal of producing a nuclear-powered aircraft is an admittedly ambitious one, it is only such high-performance, premium uses of energy which can today justify the consumption of as rare a resource as uranium-235 or plutonium-239. Moreover, it is inescapable that a development of this type has great military significance.

"In recent months, the Government has announced that the nuclear aircraft program is entering a new phase. In this new phase, the Aircraft Gas Turbine Department of the General Electric Company has been given the responsibility for the propulsion system, and the Consolidated Vultee Aircraft Corporation is to supply an air frame.

"My belief is that our efforts to fly an aircraft on nuclear power will be successful. The difficulty of the task and the value of the result combine to form a challenge that is, in my opinion, unmatched."

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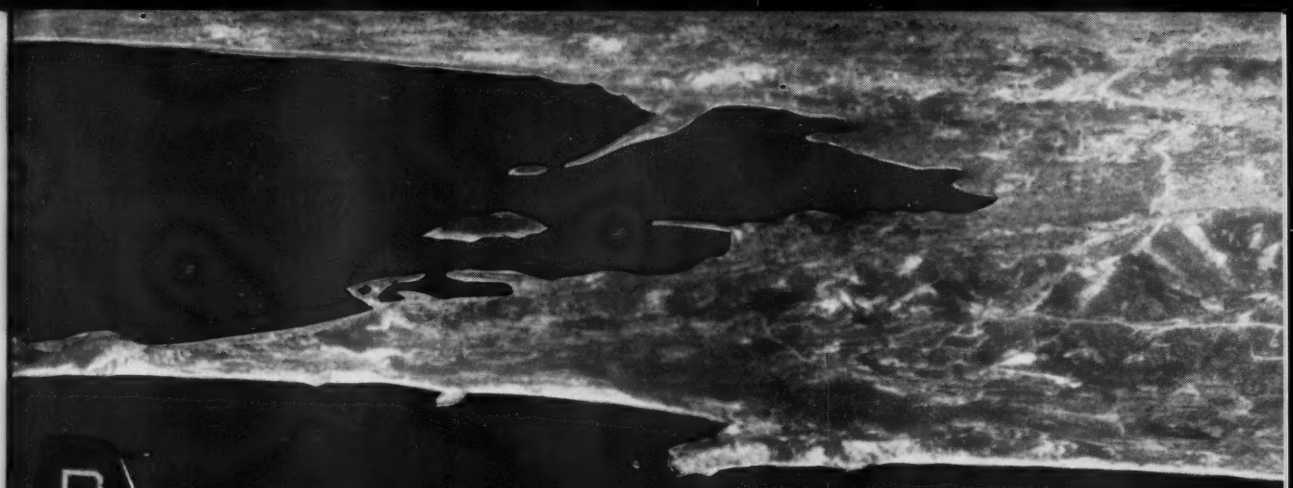

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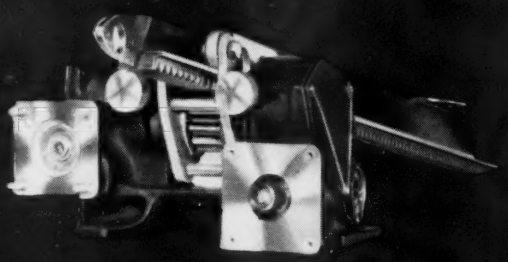

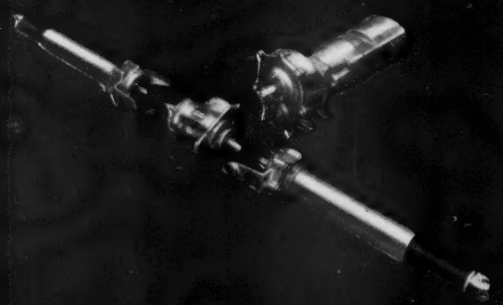

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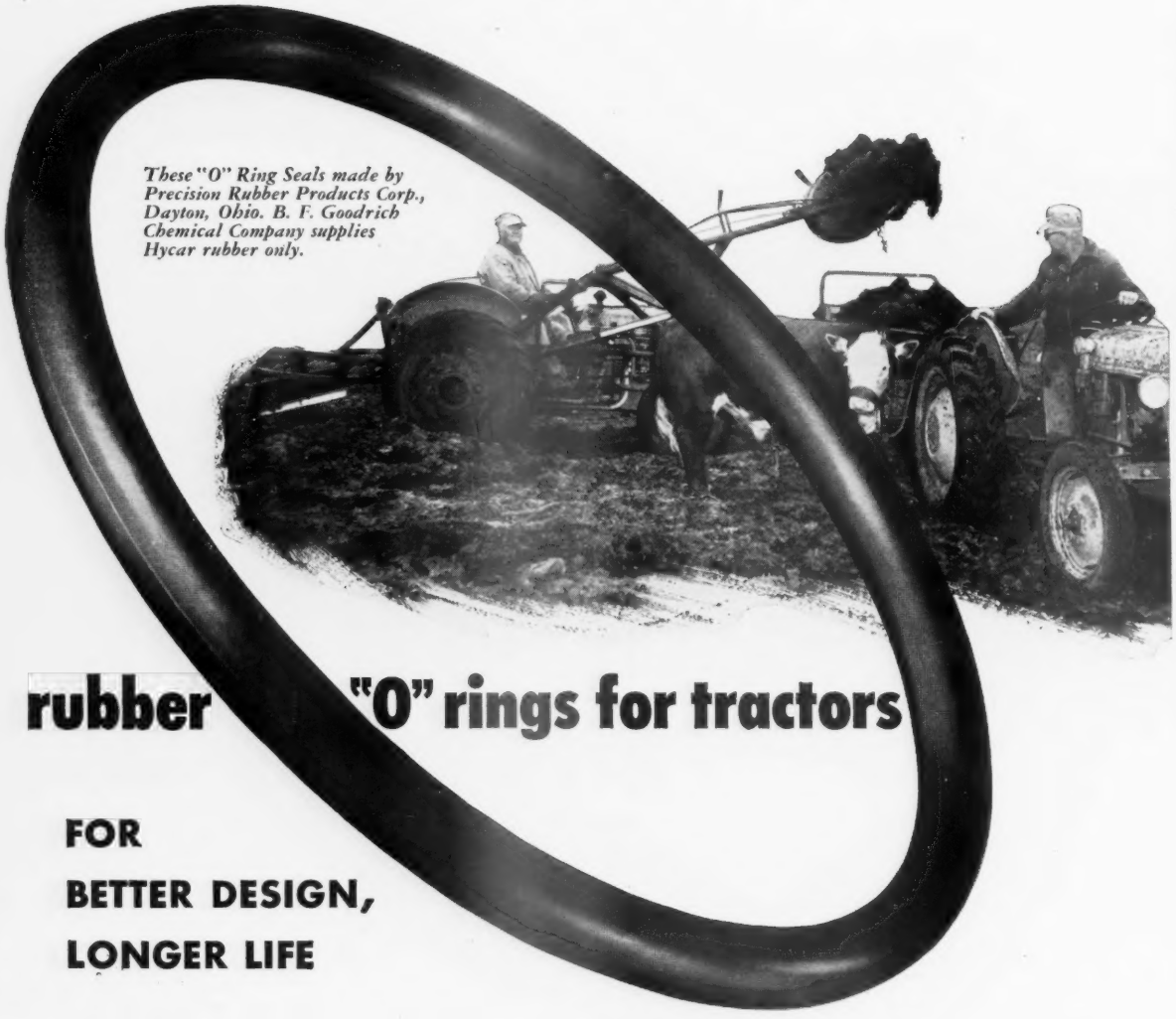

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A Study of an Analogous Model Giving the Nonlinear Characteristics in the Buckling Theory of Sandwich Cylinders

By

Chi-Teh Wang and G. V. R. Rao
New York University

In previous papers, the problem of buckling of sandwich cylinders under axial compression has been investigated both theoretically and experimentally. For sandwich cylinders with weak core, it was found that the buckling load given by the small deflection theory checks well with the experimental one. Whereas, for homogeneous cylinders, it is well known that this is not the case, and the buckling phenomenon must be explained by the nonlinear large deflection theory. The limiting case of a sandwich cylinder with a strong core is a homogeneous cylinder. Thus, the weakness of the shear rigidity of the sandwich cylinder must have compensated the importance of the nonlinear terms in the large deflection theory. To show this effect, nonlinear theory must be applied to sandwich cylinders with various degrees of weakness in the shear rigidity of the core. This, however, is a difficult problem. With a view to getting a qualitative picture in this respect, a model originally proposed by von Kármán, Dunn, and Tsien which will reproduce the nonlinear behavior in the buckling phenomena is studied, and a satisfactory explanation is obtained.

Air Drag on Cubes at Mach Numbers 0.5 to 3.5

By

George E. Hansche and John S. Rinehart
New Mexico School of Mines

The air drag on two sizes of steel cubes, $^1/_4$ in. and $^3/_8$ in., has been carefully determined in the approximate range from Mach Number 0.5 to 3.5. In general, the results are consistent and in substantial agreement with similar data obtained by Charters and Thomas on spheres. The present data do not yield an explicit value of the drag coefficient C_D but rather an average value of the quantity C_DA for a rotating cube where A is proportional to the area of the cube. An "average" value for A of 1.50 d^2, where d is the length of one edge of the cube, is assumed and C_D calculated. The two sizes of cubes give essentially equal values for C_D at corresponding Mach Numbers.

Compressibility Corrections for Bodies of Revolution

By

Boris A. Rabineau
Douglas Aircraft Company

An approximate formula for a compressibility correction on bodies of revolution at 0° angle of attack is derived. The maximum perturbation velocity calculated by this formula on a 12 per cent thick body at a Mach Number of 0.9 agrees within 0.5 per cent with the results of more elaborate calculations based on potential theory and Goethert's three-dimensional rule. The perturbation-velocity peaks are located, in this case, at 10 per cent of the body length from the body ends and increase 76 per cent between $M = 0$ and 0.9. The same formula applied to the experimental data at a Mach Number of 0.9 on a 4.5 per cent thick body with elliptical ends (each end having a thickness ratio of 15 per cent) gives the maximum perturbation velocity (at 7.5 per cent of the body length from the nose) with an error of 0.08 to 0.15 per cent of the free-stream velocity and about 2 to 3 per cent of the perturbation velocity.

On Pohlhausen's Method with Application to a Swirl Problem of Taylor

By

J. C. Cooke
University of Malaya

Most applications of Pohlhausen's method to three-dimensional laminar boundary-layer flow have assumed a "thickness of the boundary layer" δ, at which the velocity in the boundary layer becomes equal to the velocity in the main stream. However, in solving problems, the velocities over the surface are split into components at right angles, and each component is supposed to reach the corresponding main-stream component in the same distance δ. It is asserted in this paper that this is not correct, and examples are given to show that the assumption leads to results much less accurate than those of which the method is capable. The method is illustrated by the solution of a swirl problem solved by Taylor. The algebraic and numerical work is heavy even for cases where there is symmetry of some kind, as there is in Taylor's problem.

Determination of Elastic Wing Aerodynamic Characteristics

By

William J. Gaugh and Joseph K. Slap
Northrop Aircraft, Inc.

The basic aeroelastic integral equation is formulated by treating the wing as a tapered cantilever beam mounted normal to its straight elastic axis. By means of an iterative process, a series solution is obtained for the aeroelastic change in angle of attack distribution. For swept-back wings, this Neumann solution fails to converge at dynamic pressures that exceed the absolute value of the divergence dynamic pressure even though the latter is negative and the wing is physically stable. This eigenvalue problem is handled by expanding the series about a new point and thus effectively increasing the radius of convergence to agree with the physical case. It is shown that the new point, expressed by a convergence factor, can be chosen to improve the rate of convergence of the series.

The aeroelastic effects on the stability derivatives, on the hinge moments, and on the effectiveness of the control surfaces are investigated and shown to be expressible as simple functions of the dy-

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Result: TIME-SAVING

KEEPS PLANES ON SCHEDULE BY ELIMINATING HIT AND MISS TROUBLE SHOOTING

Even before the wheels touch the runway, the ignition fault has been pin-pointed and a maintenance crew stands by to make a fast repair. Minutes later the ship departs *on schedule*. The fast, certain repair job was possible because the trouble shooting was done in flight, by the operator of a Bendix Ignition Analyzer. While making a routine check of several plugs the scope reading showed a trouble pattern. The operator quickly analyzed the location and seriousness of the trouble and the word was radioed ahead. Meanwhile, the pilot reduced power of the malfunctioning engine to cool it in flight and ready it for maintenance. Just such a case as this is the reason why one airline has reduced turn-around time by 18% with the Bendix Ignition Analyzer. It can do the same for you and much more besides.

Write us for free literature concerning the Bendix Ignition Analyzer.

Costs Less—Does More

The Bendix Ignition Analyzer is available for either airborne or portable-airborne installations. It can be used with either high or low tension magneto or battery ignition. It is the ignition analyzer that can predict spark plug failure before it occurs . . . make an efficient check of more than one spark plug at a time and do so on a large, easy to read screen . . . yet it costs less than comparable analyzers.

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namic pressure. Wind-tunnel data for a full-scale sweptback wing are presented and agree well with results calculated using the present method.

Preprint No. 318

Analysis of Nonuniform Columns and Beams by a Simple D-C Network Analyzer

By

George W. Swenson, Jr.

Washington University

The analysis of beams, columns, and beam-columns whose flexural rigidities and/or lateral loadings are arbitrary functions of position can be solved with the aid of a simple electric network analyzer. In the case of the column, the lowest critical load can be determined with considerable accuracy. The electric network is of ladder configuration, with displacements represented by node-pair voltages and moments by currents. The column problem requires the use of a number of "negative resistors" that are simulated by sub-networks of positive resistors and adjustable voltage sources.

Problems are discussed which illustrate the application of the analyzer. In the case of a column with a single abrupt transition in rigidity, the value of the critical load is determined to within 0.5 per cent of the analytically calculated value.

Theoretical Investigation of Several Types of Single-Degree-of-Freedom Flutter

By

Harry L. Runyan, Herbert J. Cunningham, and Charles E. Watkins

Langley Aeronautical Laboratory, N.A.C.A.

The possibility of an undamped oscillation of an airfoil (or aerodynamic body) with a single degree of freedom in potential flow was first noted by Glauert in 1929 but had received relatively little attention until recently. These undamped oscillations might have a direct bearing on problems of both "dynamic stability" and "flutter" of airplanes. Because of the many configurations of airplane design now being considered and because of the wide operational ranges of speed and altitude, knowledge of these single degree phenomena becomes more significant.

The present paper gives theoretically predicted effects of several primary parameters associated with single-degree-of-freedom flutter. Specific problems dealt with are: (a) pitching oscillation of an unswept wing, oscillation of an aileron about its hinge axis, and bending oscillation of a swept wing in subsonic streams; (b) pitching of an unswept rectangular wing, pitching of a delta or triangular wing, and oscillations of an aileron about its hinge line, in supersonic streams.

Results for one series of experiments that confirm the existence of single-degree-of-freedom pitching flutter of an unswept wing at low speeds are included.

Preprint No. 323

Measurement of Instantaneous Vector Air Velocity by Hot-Wire Methods

By

Carl Pearson

Harvard University

One of the major problems encountered in improving the design of jet-engine compressors has been to examine experimentally the airflow present in any given compressor stage. Because of the rapid and large fluctuations in velocity, the usual types of instrumentation will give a (doubtful) measure of the average velocity alone. However, a hot-wire probe has been developed which permits measurement of instantaneous, as well as average, direction and magnitude under the above conditions of airflow.

Details of the construction, theory, and use of this hot-wire instrument are presented. Each wire used need be calibrated only once; although the characteristics of a given wire change rapidly and somewhat erratically, a correction method has been devised which automatically compensates for such changes. This correction method, based on the hypothesis that the changes in characteristics are due to a combination of oxidation and plastic flow of the hot-wire material, has been firmly validated by extensive experimental work.

In the measurement of instantaneous air velocity, it might appear that, because of the predominant effect of the heat capacity of the wire, the instantaneous velocity should be proportional to the rate of change of voltage across the hot-wire. This is indeed the case, but to prove this rigorously (for large velocity changes), as well as to determine the constant of proportionality, requires considerable algebraic manipulation.

There are many ways in which the present theory may be checked experimentally; in general, the agreement is excellent. A typical example is given in which the instantaneous air velocity behind an axial compressor is measured in three different directions.

The instrument has so far been examined only for Mach Numbers less than 0.7. For $M < 0.3$, an accuracy of better than 3 per cent in average and 10 per cent in instantaneous velocities is claimed; at $M = 0.7$, the error in instantaneous velocity measurement may be 25 per cent.

It appears that hot-wire instruments of the present type will extend considerably the range of experimental work possible in compressors and other mechanisms. The instrument as here discussed has now been used satisfactorily over a period of about one year in the analysis of the airflow in the axial and centrifugal compressors, both in and out of pulsation.

An Experimental Investigation of the Isothermal Laminar Boundary Layer on a Porous Flat Plate

By

Paul A. Libby, Lawrence Kaufman, and R. Paul Harrington

Polytechnic Institute of Brooklyn

The transition Reynolds Numbers and velocity profiles of the laminar isothermal boundary layer on a porous flat plate with suction or injection have been measured and compared with the laminar boundary-layer analyses that have been carried out in the past several years. The results indicate that porous plates closely approximating the mathematical or ideal porous plates can be realized and that the theoretical velocity profiles are in good agreement with experiment.

On Unsteady Nonlinearized Conical Flow

By

S. F. Borg

U.S. Naval Postgraduate School

It is shown that the equations of unsteady, nonlinear, nonviscous, nonheat-conducting flow may be put in a conical form. The problem of a shock striking an infinite wedge is considered. An invariance relation is established, and certain properties of the reflected shock are examined. These include a discussion of a possible form of reciprocal flows, a calculation indicating the impossibility of a certain reflected shock shape for air, and, based upon an analysis of the characteristics of the flow, a nonexistence proof for certain combinations of shock strengths and wedge angles.

American Helicopter Society News

F. N. Piasecki Presents Paper at Regional A.H.S. Meeting

An overflow crowd of 500 people attended a joint meeting of the Eastern Regional Chapter of The American Helicopter Society, the Philadelphia Section of the Institute of Aeronautical Sciences, and the Franklin Institute held at the Franklin Institute in Philadelphia on November 7.

F. N. Piasecki, Chairman of the Board, Piasecki Helicopter Corporation, spoke on "The Development of the Tandem Helicopter." Coauthors of the paper with Mr. Piasecki were A.H.S. members Elliot Daland and Donald N. Meyers.

The paper brought forth the philosophy used in the development of the new tandem configuration at a time when the helicopter itself was in the pioneering stage of development. The paper used the development of the tandem helicopter as a case example to demonstrate development philosophy rather than merely to recount the history of the tandem alone, although many interesting early tandem helicopter designs were shown and discussed.

The design challenge of the first tandem helicopter was primarily one of the proper combination, integration, and arrangement of the multitude of components, as well as the necessary detail design of the parts. It was important to go into detail on all aspects of the machine at the beginning, in order that the proper combination and arrangement of components could be attained while the design was still flexible enough to permit rearrangement.

Since the machine's success depended upon the reliable functioning of all of its components, much ground or bench testing was employed to prove the ability of each assembly to operate under simulated flight conditions. This is particularly true in the case of the helicopter, where nearly all of the vital parts are subjected to dynamic and vibrational loads.

The philosophy demonstrated in the development of the tandem helicopter was shown to be applicable to many complex engineering projects and particularly to aircraft, where the unknowns are numerous and closely interrelated, where the risk of actual flight testing is large, and where weight and service life are prime considerations.

This philosophy was summarized in the following steps:

(1) Establish functional requirements prior to design.

(2) Initially choose good design on the basis of all of the best information available.

(3) Set up priority of the problems; isolate the critical unknowns of the design in order to work on them first.

(4) Make a "blitzkrieg" effort in the construction of the critical components and testing thereof to reduce overall development time.

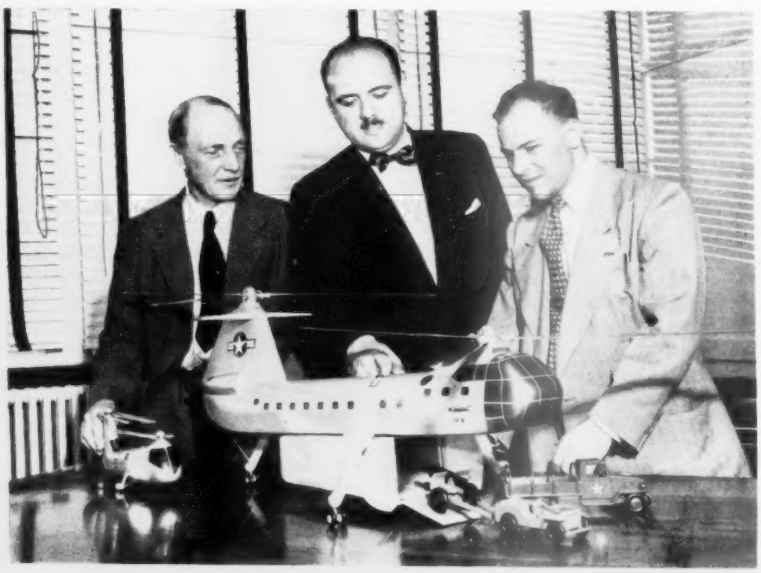
(5) Turn test results into redesign, but only where required. Continue tests until full-scale machine is tested. Discover weak points in initial functional requirements.

(6) Follow-through design into production. Add customers' detail specifications to design and repeat steps of testing again, changing only when necessary. Use motto: *When it is not necessary to change, it is then necessary not to change.*

(7) (a) Retesting, amplified with better knowledge of operating conditions from the full-scale tests. (b) More testing to assure high degree of reliability. (c) Make only necessary changes. (d) Test these changes.

The paper concluded on the theme that, in these days of increasing tension and danger, the engineer must make every effort to shorten the elapsed time required for the development of new equipment, as well as to assure continuity of development. This dual challenge of optimum development in minimum time demands a careful balance between theoretical analysis and practical cut-and-try methods.

Coauthors of Paper Presented at November 7 Meeting: *Elliot Daland, Frank N. Piasecki, and Donald N. Meyers (left to right), coauthors of the paper entitled "Development of the Tandem Helicopter" which was delivered at the Franklin Institute on November 7, are shown inspecting a model of the XH-16 Tandem Transport Helicopter.*



▸ **Eighth Annual Forum Preparations**—The Eighth Annual Forum will be held in Washington, D.C. on May 15 and 16, 1952. The Washington Hotel will be Forum Headquarters. A Helicopter Air Show will be coordinated with Armed Forces Day activities on May 17.

The Honors Night Banquet is tentatively scheduled for the evening of May 15 with the Pioneers' Night Dinner on May 16.

The Forum Committee members, under Chairman Steve Tremper, include: Charles Lefever, Technical Chairman; Jack Beighle, Dinners; Jean Ross Howard, Arrangements; and Ed Odlum, Helicopter Air Show.

Additional Committee members for proceedings, publicity, and industrial displays will be announced shortly.

T. R. PIERPOINT
Vice-President, Mid Eastern Region, A.H.S.

I.A.S. News (Continued from page 7)

safely operable at these speeds." The presentation was made on October 29 by Secretary of Defense Robert A. Lovett.

▸ **Harold Gatty** (A.F.), Owner, Fiji Airways, launched a new internal air service last September in the Fiji Islands.

▸ **Frank N. Piasecki** (A.F.), Chairman of the Board, Piasecki Helicopter Corporation, was given the Aviation Award for 1950 by the Trans World Airline Employees Club of Philadelphia. Mr. Piasecki was selected as the individual who had done the most for the advancement of aviation in Philadelphia during the past year. His principal contribution, the citation states, has been his success in building up the largest organization in the Philadelphia area engaged in the production of aircraft.

▸ **Alan Pope** (M.), Associate Professor, Daniel Guggenheim School of Aeronautics, Georgia Institute of Technology, is currently with the Wind Tunnel Group, Sandia Corporation, Albuquerque, N.M.

▸ **Haraden Pratt** (A.F.), Vice-President, American Cable and Radio Corporation, has been appointed Telecommunications Advisor to the President of the United States. Mr. Pratt's offices are in the Executive Office Building, Washington, D.C.

PROMOTED BY CONVAIR

Frank W. Davis (M.), who since 1947 has been serving as Chief Design Engineer, San Diego Division, Consolidated Vultee Aircraft Corporation, was recently appointed Assistant Chief Engineer in charge of research and development. A graduate of California Institute of Technology, Mr. Davis was a Marine Corps pilot for 4 years before joining Convair's Vultee Field Division in 1940 as Engineering Test Pilot.

▸ **Paul Rosenberg** (M.) has moved the offices and laboratory of Paul Rosenberg Associates, Consulting Physicists, from New York City's Woolworth Building to 100 Stevens Ave., Mount Vernon, N.Y. This move will give the company expanded facilities for consultation, research, and development in the industrial and military applications of physics and related sciences.

▸ **Ernest H. Werner** (M.), who for 2 years served as Chief, U.S. Civil Aviation Mission to Ecuador, Civil Aeronautics Administration, received the decoration "Al Merito" from Ecuador's President Galo Plaza "for his [Mr. Werner's] brilliant work in the general field of civil aviation and particularly for his wholehearted collaboration and effort to improve civil aviation in Ecuador and assist the Ecuadorian Director General of Civil Aviation." Mr. Werner has now been assigned to duty in Washington, D.C.

Members on the Move

The purpose of this section is to provide information concerning the latest affiliations of I.A.S. members. All members are, therefore, urged to notify the News Editor of changes as soon as they occur.

John R. Allsup, Jr. (T.M.), now Senior Draftsman, Goodyear Aircraft Corporation, The Goodyear Tire & Rubber Company.

WEATHER BUREAU CONSULTANT

Francois N. Frenkiel (A.F.) was recently appointed a Consultant to the Scientific Services Division of the U.S. Weather Bureau in Washington, D.C. At the same time, he is giving a seminar at the Weather Bureau on "The Statistical Theory of Turbulence for Meteorologists." Meanwhile, Mr. Frenkiel retains his position on the staff of the Research Center of the Applied Physics Laboratory, The Johns Hopkins University.

Samuel B. Batdorf (M.), Advisory Engineer, Westinghouse Research Laboratories, Westinghouse Electric Corporation. Formerly, Physicist, N.A.C.A., Langley Air Force Base, Va.

Ensign Allen M. Benson, U.S.N. (T.M.), Aircraft Maintenance Officer, Naval Air Station, San Diego, Calif. Formerly, Chief Electronics Technician, U.S. Navy.

First Lieutenant Stanley Bernstein, U.S.A. (T.M.), Headquarters, 68th Medium Tank Battalion—CCB, 6th Armored Division, Fort Leonard Wood, Mo. Formerly, with Fairchild Guided Missiles Division, Fairchild Engine and Airplane Corporation.

Captain James E. Chikar, U.S.A.F. (T.M.), Instructor of Combat Crews, Randolph Air Force Base, Tex. Formerly, Engineering Trainee, Allegheny Ludlum Steel Corporation.

William A. Clegern (T.M.), Chief of Engineering Flight Tests, Fort Worth Division, Consolidated Vultee Aircraft Corporation. Formerly, Assistant Project Engineer, Convair.

Lieutenant Warren F. Clement, U.S.A.F. (T.M.), now O.M.S., Lowry Air Force Base, Colo.

Michael M. Conea (M.), Senior Project Engineer, Canadair, Ltd. Formerly, with Fireproof Tanks, Ltd., Portsmouth, Hants, England.

Private First Class John H. Dobbins (T.M.), "A" Btry., 41st F.A. Bn., Fort Benning, Ga. Formerly, Junior Planning Engineer, Chase Aircraft Company, Inc.

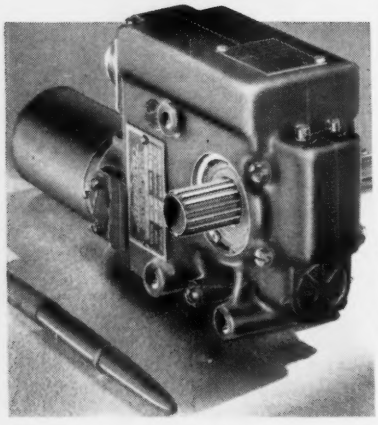
R. Boyd Ferris (T.M.), Personal Assistant to Chief Project and Development Engineer, British European Airways,

NEW POSITION AT BOOTS

J. Nelson Kelly (A.M.) was recently promoted from Vice-President of Boots Aircraft Nut Corporation to Executive Vice-President of the firm. He has been actively engaged in flying since World War I, when he served as combat pilot with the 93rd Pursuit Group, A.E.F. A Colonel in the U.S. Air Force Reserve, Mr. Kelly was called to active duty during World War II and shortly after his discharge joined Boots.

ROTORAC

high torque rotary actuator with load-sensitive switches



The limit switches of the R-450 Rotorac can be set for any torque value up to 300 pound inches. With positive internal stops, travels up to 270 degrees may be obtained. Without them, the Rotorac can be used for multiple revolution travel.

The R-450 Rotorac has a double-ended splined output shaft. It will operate doors, valves or any other equipment requiring rotary actuators.

At a load of 250 pound inches, speed is 5 rpm, and the current consumption 3.5 amperes at 26 volts D.C.

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England. Formerly, Engineer, Patents Department, A. V. Roe Canada Limited, Canada.

George F. Gottschalk (T.M.), now Stress Analyst, Thieblot Aircraft Company, Inc.

Dr. Fausto G. Gravalos (M.), Technical Engineer, Aircraft Gas Turbine Divisions, General Electric Company. Formerly, Associate Professor of Aeronautical Engineering, Rensselaer Polytechnic Institute.

Ernest J. A. Greenwood, Jr. (A.F.), Chief Engineer, Norden Instruments, Inc. Formerly, Project Engineer, Hamilton Standard Division, United Aircraft Corporation.

Second Lieutenant Roy E. Hale, Jr., U.S.A.F. (T.M.), Wind Tunnel Branch, Aircraft Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio. Formerly, 3401st Student Sq. (O), Keesler Air Force Base, Miss.

Joseph S. Islinger (T.M.), Assistant Research Engineer, Applied Mechanics Research Division, Armour Research Foundation, Illinois Institute of Technology. Formerly, Instructor and Chairman, Department of Physics, Elmhurst College.

Second Lieutenant Samuel Kafoury, U.S.A.F. (T.M.), 3401 Student Sqn. (O), Keesler Air Force Base, Miss. Formerly, Private, Sheppard Air Force Base, Tex.

Orton A. Larson (T.M.), now Junior Engineer, Boeing Airplane Company. Formerly, Student.

Captain David W. Lueck, U.S.A.F. (M.), Acting Chief, Special Projects Branch, Airplane Division, Air Research and Development Command, Baltimore, Md. Formerly, Professor of Aerodynamics, U.S.A.F. Institute of Technology, Wright-Patterson Air Force Base, Ohio.

Agne T. Lundgren (M.), Chief Engineer, Industrial Development Division, Trans Ocean Airlines. Formerly, Project Engineer, Hills Brothers Coffee, Inc.

M. Mitrovich (M.), Production Design Engineer, Chance Vought Aircraft Division, United Aircraft Corporation. Formerly, Chief Engineer, Regent Aircraft Corporation.

Harry B. Picken (M.), now President and Chief Engineer, Genaire, Ltd., Canada.

Ernest F. Relf, (F.), Consultant, Government Research Departments, England. Formerly, Principal, The College of Aeronautics, England.

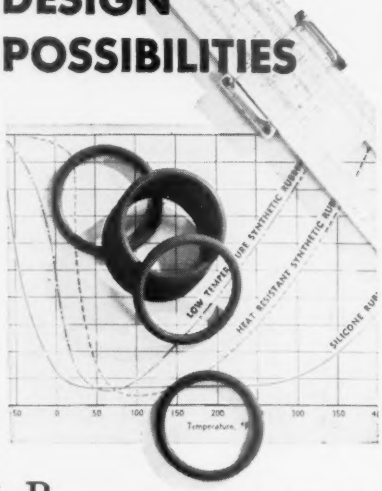
Alfred Ritter (T.M.), Mechanics Branch, Office of Naval Research, U.S. Navy. Formerly, Student, Cornell University.

Maurice S. Sevelson (T.M.), Design Engineer, Fletcher Aviation Corporation. Formerly, Research Engineer, Personal Aircraft Research Center, Agricultural and Mechanical College of Texas.

Bert A. Shields (M.), General Rules Division, Civil Aeronautics Board, Washington, D.C. Formerly, Head, Aviation Section, Navy Training Publications Center, Bureau of Naval Personnel, Department of the Navy.

Professor F. R. Steinbacher (A.F.), Chief, Structures Branch, Engineering

SILICONE "O" RINGS OFFER UNIQUE DESIGN POSSIBILITIES



Because of the inherent stability of silicone rubber, Arrowhead "O" rings molded of this remarkable new material provide a long-lasting seal under conditions far beyond the limits of ordinary rubbers. For example, they remain flexible at -130° F.; withstand indefinitely, exposure to temperatures of 500° F. and over. They offer excellent resistance to oxidation, to many oils, acids, alkalies and a variety of chemicals. The ideally inert characteristic of these seals is demonstrated by their astonishing resistance to aging, even at abnormally high temperatures. At normal temperatures they last *indefinitely*. For superior performance under severe conditions, consider silicone rubber. Arrowhead's *silicone specialists* will welcome your inquiry.

Write FOR ENGINEERING DATA

Free to Engineers—two valuable new publications on silicone rubber and "O" rings. Contain complete technical and descriptive data, including typical applications.

ARROWHEAD RUBBER CO.

Division of National Motor Bearing Co., Inc.

DOWNEY (Los Angeles County) CALIF.

"O" RINGS ♦ SILICONES ♦ ~~AIRTRON~~ DUCTS

Division, DCS/Research and Development, Arnold Engineering Development Center, Tullahoma, Tenn. Formerly, Department of Aeronautical Engineering, University of Alabama.

Dr. Victor G. Szebehely (M.), Hydrodynamics Division, David Taylor Model Basin, Department of the Navy, Washington, D.C. Formerly, Assistant Professor of Applied Mechanics, Applied Mechanics Department, Virginia Polytechnic Institute.

Aviation Cadet Donald C. Thompson, U.S.A.F. (T.M.), 3307 Training Squadron, Flight B, Squad 5, Marana Air Force Base, Ariz. Formerly, Engineering Technician "A," Northrop Aircraft, Inc.

Allen Whitlock (A.M.), Material Procurement, Aero Service Corporation. Formerly, School Director, Rising Sun School of Aeronautics.

C. E. Willis (M.), Sales Manager, National Water Lift Company. Formerly, Manager, New York Office, Lear, Inc.

Harold V. Wright (M.), now Managing Director, Bristol Aeroplane Engines, Ltd.

William C. Zint (A.M.), now Department Head, Longines-Wittnauer Watch Company, Inc.

Necrology

Edwin F. Schoch

Edwin Foresman Schoch, T.M.I.A.S., was killed on his thirty-fifth birthday, September 13, 1951, in the crash of an F2H-2 twin-jet Banshee while conducting a test flight in the vicinity of Elsberry, Mo., 45 miles north of St. Louis.

Joining the Engineering Division of McDonnell Aircraft Corporation in November, 1945, one month after his release from the U.S. Navy, Ed Schoch was quickly moved to the position he held at the time of his death as Experimental Engineering Test Pilot. At McDonnell, he flew the FH-1 Phantom, the XF2H-1 experimental Banshee, the XF-88 Voodoo, the F2H-2P photographic Banshee, and the F2H-3 Ban-

shee. He is believed to have been the only pilot who has ever flown the McDonnell XF-85 Goblin, the Air Force's experimental "parasite" jet fighter.

Born in Oakmont, Pa., Mr. Schoch attended the South Park High School in Buffalo, N.Y. and then spent 2 years as a railway clerk before entering Virginia Polytechnic Institute from which he was graduated in 1941 with mechanical and aeronautical engineering majors. Shortly after his graduation, he joined the U.S. Navy and took his basic flight training at the Elimination Training Base, Anacostia, D.C. He received his advanced training at Jacksonville, Fla., and in April, 1942, was designated a Naval Aviator and commissioned an Ensign. After serving for a period of time as a basic and fighter flight instructor, he was assigned to the Pacific Theater of Operations as a fighter pilot. He was credited with four Japanese airplanes and was the recipient of the Navy Cross, the Distinguished Flying Cross, and the Air Medal. He was released to inactive duty as a Lieutenant (senior grade) in 1945.

Mr. Schoch is survived by his widow, Arlene Schoch, and his four children: Raymond, aged 7; Linda, aged 5; Susan, aged 4; and Claudia, aged 1.

Corporate Member News

• **AiResearch Manufacturing Company, Division of The Garrett Corporation**. . . Small auxiliary gas-turbine engines, air-turbine starters, and control valves for seven types of Navy turbojet and turboprop aircraft are being produced for the U.S. Navy's Bureau of Aeronautics. AiResearch's gas turbine is said to be the first small unit of its type in the 100-hp. class to get into field use and operate successfully. . . A new gas-turbine test cell building has been completed at the Los Angeles plant. The test cells are to be used for both developmental and production gas-turbine compressors and gas-turbine power units. Complete units will be tested in three of the cells, and accessory testing will be carried on in another one . . . A certificate of Merit was awarded to AiResearch for its program of employing physically handicapped personnel. The award was given by the Centinela Valley Committee for the Employment of the Physically Handicapped.

• **Allis-Chalmers Manufacturing Company** . . . A bulletin, "Allis-Chalmers Package Pumps," 52B7529, which describes these pumps engineered for a wide range of fractional horsepower application, including air conditioning, in capacities to 80 gal. per min. at heads to 100 ft., is available upon request.

• **Allison Division, General Motors Corporation** . . . The J-35-23 jet engine has been redesignated by the U.S. Air Force and is now the J-71. This engine develops more than 8,000 lbs. of thrust.

• **Aluminum Company of America** . . . Thomas D. Jolly, Vice-President in Charge of Engineering and Purchases, was presented with Carnegie Institute of Technology's Merit Award for "worthy achievement." The presentation took place on October 20 at Carnegie's Homecoming Luncheon.

• **American Helicopter Company, Inc.** . . . The new helicopter power-plant manufacturing and test facility at Falcon Airfield, Mesa, Ariz., has been opened. The new center consists of 40,000 sq.ft. of floor space and 700 acres of adjoining airfield. It will provide additional facilities for the helicopter and pulse-jet power-plant work.

• **American Steel & Wire Company** . . . Walter E. Mackley, New York District Sales Manager, died on October 19 of a heart attack suffered while attending a convention in Atlantic City, N.J.

• **Bell Aircraft Corporation** . . . A vibration test tower, 40 ft. high and 15 ft. square, has been made of structural steel framework for use in studying the vibration effects on aircraft and guided missile components. The tower, a giant cocktail shaker, is capable of subjecting aircraft parts and components weighing up to 3,000 lbs. to vibration frequencies of from 1 to 15 cycles per sec. Maximum amplitude of vibration is 5 ft. A control house is located 30 ft. from the tower's base and contains all control apparatus, as well as visual and recording instruments.

• **Bendix Aviation Corporation** . . . A 75-lb. jet-engine self-starter that requires only 3.5 sec. to bring a jet engine to starting speed was demonstrated last October. As soon as the engine is brought to starting speed by this 380-hp. starter, it cuts out and the engine is "on its own" within 10 sec. It was designed specifically for use on the J-65 Sapphire jet engine.

• **Boeing Airplane Company** . . . "Gushing Gertie," a 4-lb. centrifugal-type water separator with cyclonic rotor attachment is Boeing's answer to the elimination of snow storms and other foul weather conditions inside the cabins of high-speed jet aircraft. Gertie, said to be 80 per cent efficient, is earmarked for early installation on each B-47 Stratojet medium bomber . . . A guided missile test group has been stationed at the U.S.A.F. Missile Test Center, Patrick Air Force Base, Fla. . . . The first of several B-47 Stratojet bombers to be assigned to the U.S.A.F. Strategic Air Command arrived at MacDill Air Force Base, Fla., from Wichita, Kan., on October 24. The 1,090-mile flight was accomplished at an average speed of 575 m.p.h. in 1 hour and 50 min.

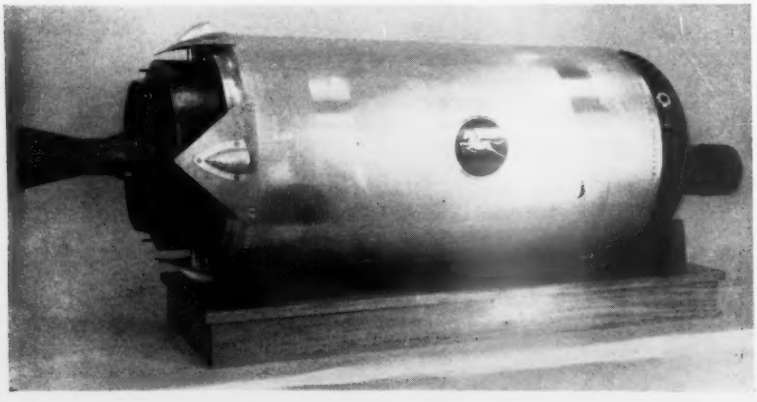
• **Breeze Corporations, Inc.** . . . John T. Mascuch, President of Breeze, died on October 26 at The Johns Hopkins Medical Center after a brief illness.

• **Brown Instruments Division, Minneapolis-Honeywell Regulator Company** . . . A new potentiometer circuit that permits measurements of spans as narrow as 100 microvolts has been developed. In addition to direct voltage determinations, the instruments are useful (with appropriate primary measuring elements) for the precise measurement of differential temperatures and the accurate determination of slight variations in the temperatures of small objects through the use of radiation pyrometry.

• **Consolidated Vultee Aircraft Corporation** . . . A limited number of new twin-engine turboprop airplanes is being produced for the U.S. Air Force. Patterned after the Convair-Liner 340 and the T-29, the new planes will be used for service-test purposes. Initially, they will be powered with Allison T-38 turbine engines . . . The 44-passenger Convair-Liner 340 made its first flight on October 5. . . Three undergraduate courses in engineering—Analytical Mechanics (statics), Differen-

NEW 1,000-LB. THRUST TURBOJET

The Fairchild Engine Division of Fairchild Engine and Airplane Corporation has announced the development of a turbojet engine of 1,000-lb. thrust. While neither its applications nor its specific performance data have been revealed, the engine is known to be approximately 6 ft. in length by 2 inches in diameter and weighs 325 lbs. with complete accessories. It bears the designation J-44 and is being produced for both the U.S. Navy and U.S. Air Force.



What's doing at JACK & HEINTZ

Actuators Prove Value of Intercompany Engineering

OFFER WIDE RANGE OF PROTECTION

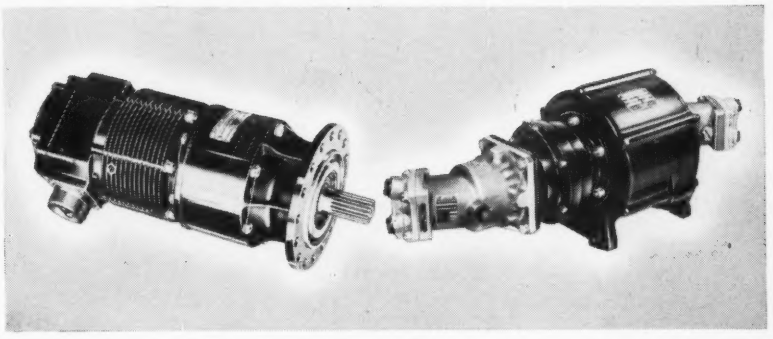
Jack & Heintz regularly engineers into special-purpose electric and hydraulic actuators such features as brakes, disconnects, emergency drives, automatic positioning, and torque-limiting clutches.

Successfully combining one or more of these features into a particular unit is invariably the result of close co-operation between airframe engineers and ourselves. Established designs with proven features serve merely as a starting point for us in developing actuators for your special needs.

Some of the advanced design features of Jack & Heintz actuators include brazed commutator connections and elimination of banding wire on armatures. The ingeniously designed torque-limiting clutches, incorporating 10 years of research and development on both materials and lubricants, provide long wear, ease of adjustment and minimum weight.

Where short stopping times are important, brakes of our own design, or an automatic disconnect of the output shaft, can be incorporated on the actuator to prevent overrun.

These features, and many others, can be designed into either electric or hydraulic actuators engineered to your needs.



NO SUCH THING AS A TYPICAL J&H ACTUATOR—The units shown here are special-purpose actuators built by working closely with our customers' engineers. The rotary actuator on the left is electric. That on the right is hydraulic. Each represents the successful solution of specific problems.

Chief Engineer's Corner

One section of our Engineering Department is devoted solely to the design and development of actuators. This section is staffed with some of the most competent of all of our mechanical and electrical engineers. Men assigned to this section are carefully screened to make sure that they have a genuine interest in aircraft, since a knowledge of the actual airplane requirement is of prime importance in the design of actuators.

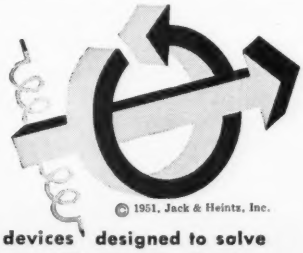
Many times we find that it is next to impossible to define all of the requirements for actuators by specification, and we then send our engineers to the airplane plant to see the actual installation, discuss requirements with the customer's engineers, and get an actual "feel" of the job to be done. Sometimes we end up with a bigger job than our customer originally intended, and produce an actuator design that takes on a larger portion of the airplane system than the first inquiry, and thereby eliminate other assemblies and simplify the over-all system.

In other instances, we find that an actuator built to the specification does not make for the reliability, ease of maintenance, etc., that we know our customers would want, even though these factors are impossible to fully cover by specification. In a matter of hours, our design engineers can be in your plant, discussing the details of an actuator design with your engineers. With them, they carry a wealth of experience on torque-limiting devices, gearing, mechanisms, brakes, etc., all of which can be put into a design especially for your application.

In addition to knowing what we can do, they also have many years of experimental work on thousands of research and development programs, so that they are aware of the unsuccessful experiments which can save you many headaches in the future. They will give you honest answers to your questions, rather than glowing promises dreamed up to sell you a J&H product.

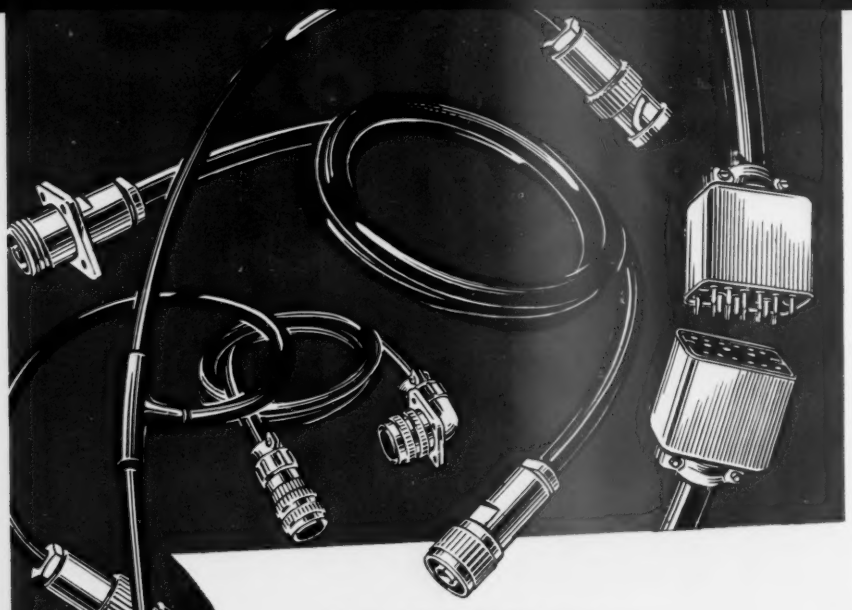
These engineers are as close to you as your telephone. We'll be only too glad to discuss your actuator problems with you. Write JACK & HEINTZ, INC., Dept. 103, Cleveland 1, Ohio.

JACK & HEINTZ *Rotomotive* EQUIPMENT



© 1951, Jack & Heintz, Inc.

means electrical, hydraulic or mechanical devices designed to solve unusual problems of developing power, controlling it, or using it.



PREPAREDNESS PRODUCTION Enlists

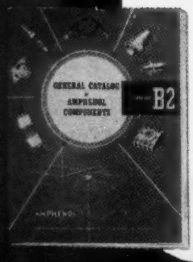
AMPHENOL

CABLE HARNESSES produced by Amphenol are assembled with the same care and rigid inspection that characterizes *all* components manufactured by Amphenol. Electrical inspection includes insulation resistance, continuity and high voltage breakdown tests. All assemblies meet and are superior to the rigid Army-Navy specifications. Specifying Amphenol complete cable assemblies cuts costs, saves valuable man hours and insures against losses due to errors and rejects.

AN CONNECTORS supplied by Amphenol insure lowest millivolt drop, extra high tensile strength, polarized shells and simple assembly. Amphenol non-rotating contact solder pockets mean faster soldering and more positive contact. Amphenol has the widest selection of AN Connectors to meet current standard MIL-C-5015 shell styles and applications.

POWER PLUGS represent a new approach to the requirements of the Signal Corps for waterproof connectors. They take up very little space and provide quick connect and dis-connect under the most adverse handling conditions.

100 CONTACT CONNECTORS for all applications where a large number of circuits must be broken quickly and easily. These connectors feature dependability and long life as well as accurate alignment of the connections and positive contact.



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AMPHENOL

tial Calculus, and Analytical Mechanics (dynamics)—were recently organized at the Fort Worth Division with Southern Methodist University faculty members as instructors. A fourth course, Thermodynamics, is scheduled to begin in the near future.

• **Consultants & Designers, Inc.** . . . Murray B. Jones has become Vice-President of Sales.

• **Curtiss-Wright Corporation** . . . Frank R. O'Leary, General Manager of the Propeller Division, has been elected a Vice-President of the corporation.

• **Douglas Aircraft Company, Inc.** . . . A new model of the Navy carrier-based Skyraider series, the Douglas AD-5, is ostensibly the first "multiplex" airplane ever to be built. The basic structure of the AD-5 is a universal "chassis" that can be transformed, through the use of packaged conversion kits, into more than a dozen combat types, such as a basic attack, photographic, tow-target, passenger and ambulance transport, and a variety of radar types. . . A $60,000,000 loan has been arranged with a group of six banks. The money will be used to finance inventories and receivables and for other corporate purposes.

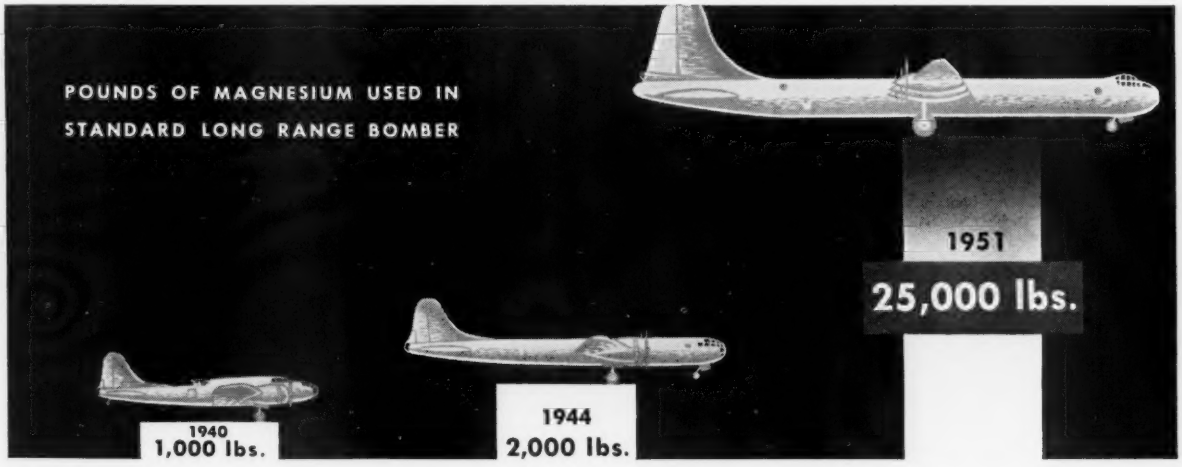
• **Eastern Air Lines, Inc.** . . . Eastern's fleet of Martin 4-0-4's are to be tagged "Silver Falcons."

• **Fairchild Camera and Instrument Corporation** . . . A $3,000,000 plant is to be built this year as the first section of $25,000,000 model "community of the future" at Jericho, L.I., N.Y. The new plant will be part of the community of Landia on a 675-acre site along the Northern State Parkway at Jericho. It will cover $4\frac{1}{2}$ acres in the center of Landia's industrial area. Both the inside and the outside of the plant will be completely landscaped, it is said.

• **General Electric Company** . . . A new "center-of-gravity" type mounting, designed to isolate the controls from vibration and shock encountered in modern high-speed aircraft, has been developed by G-E engineers in cooperation with the U.S. Navy's Bureau of Aeronautics. The new mount resembles a small platform suspended by a coil spring at each of its four corners. The control to be protected is so placed on the mount that its c.g. is equidistant from each of the four supporting springs and in the same geometric plane. This is designed to eliminate unbalanced movement and to enable the springs to withstand shock from any direction . . . A 250,000-hp. wind-tunnel drive, capable of creating supersonic blasts of air, is under construction at G-E. The unit will ultimately be installed at N.A.C.A.'s Lewis Flight Propulsion Laboratory and will be used to test aircraft power plants in the ram-jet, gas-turbine and rocket categories. . . The J-47-21 jet engine, which is rated at more than 9,000 lbs. thrust dry and one of the most powerful engines in production, has been redesignated by the U.S. Air Force and is now the J-73. . . A service shop has been opened at Strother Field, Arkansas City, Kan., for the overhaul and modification of J-47 jet engines.

• **General Electric Company and Cornell University** . . . An electronics center, to be

THEY FLY *Faster...Farther...Higher...* with



MAGNESIUM

More payload! That's what modern aircraft design demands—and that's why magnesium, the world's lightest structural metal, finds ever increasing use in air transportation. One-third lighter than the next lightest structural metal, it cuts important pounds off weight, without sacrificing strength. As a result today's bomber covers greater distances, at higher altitudes and increased speeds—with more payload!

In addition to its lightness, magnesium is easily fabricated. All forms of fabrication may be used: castings, forgings, extrusions, sheet and plate. In many cases, magnesium is actually the lowest cost metal since it permits noteworthy economies in fabrication.

Wherever a product is made to be moved or lifted, magnesium should be investigated. A vital metal in air transportation today, it offers even greater design improvements for tomorrow. Keep your eye on magnesium if your aim is light weight.

THE DOW CHEMICAL COMPANY
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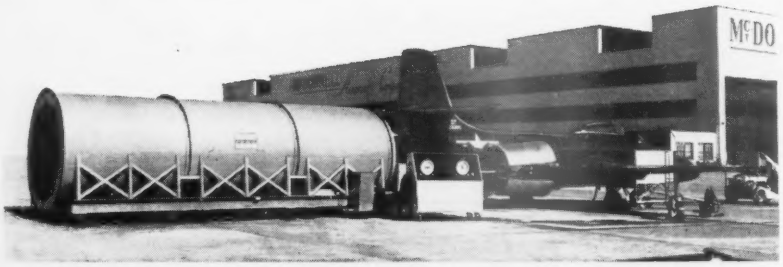
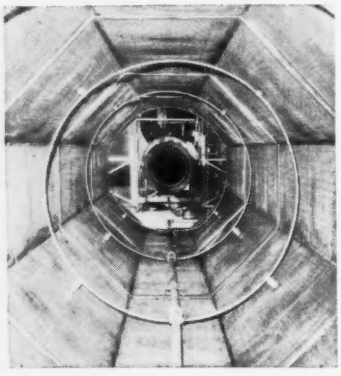
Industrial Sound Control Mufflers

QUIET the Banshee's Wail



At the McDonnell Aircraft Corporation in St. Louis, they're turning out the Navy's mighty F2H2 "Banshee" jet fighter. And like many other aircraft manufacturers McDonnell has discovered that ISC run-up mufflers make ground testing a quiet, safe, efficient operation.



Since 1937, ISC has led the field in silencing the BIG noises of aircraft engine testing. Throughout the United States and Canada, ISC mufflers, "Soundmetal" panels and other sound suppression devices are effectively subduing the excessive noise, heat, and gas velocities generated during testing. Skilled engineering, design, and installation "know how" make ISC the aviation industry's FIRST LINE OF DEFENSE against nerve-shattering noise.

Whether it's reconverting test cells for use with more powerful engines, or creating new mufflers for testing jets right in the plane, ISC is ready to solve *your* noise problem. Don't risk poor morale and inefficiency in your plant or annoyance to surrounding communities.

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Industrial Sound Control, Inc.

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known as the General Electric Advanced Electronics Center at Cornell University, is scheduled for completion in February, 1952, adjacent to Ithaca East Hill Airport. The center will carry out advanced study and development in the field of electronics and will provide scientists and engineers with "educational opportunities of a type never previously established." The efforts of the 80 persons to be employed at the center will be aimed at providing much needed electronics research and development facilities for such projects as control systems for guided missiles, electronic countermeasures, etc.

• **Globe Corporation, Aircraft Division** . . . According to a recent announcement, Globe is celebrating its fiftieth anniversary, while its Aircraft Division celebrates its thirteenth anniversary.

• **Goodyear Aircraft Corporation of The Goodyear Tire & Rubber Company** . . . A 50,000-sq.ft. building is being added to the Akron, Ohio, plant.

• **Grumman Aircraft Engineering Corporation** . . . According to reports, the new F9F-6 fighter, an advanced version of the Panther, has been successfully flown, and the first-phase flight tests have been begun. This fighter is said to feature a swept wing and a later version of the Pratt & Whitney J-48 jet engine.

• **Haynes Stellite Company, Division of Union Carbide and Carbon Corporation** . . . A new 44-page tool manual and catalog has been published. Entitled "Haynes Stellite Metal-Cutting Tools," the booklet describes, among other things, four different grades of cast cutting tool alloys. It contains approximately 80 illustrations and tables giving proper cutting angles, speeds, feeds, and depths of cut for turning, boring, and milling.

• **Industrial Sound Control** . . . Twelve test cells are being renovated for Wright Aeronautical Division of Curtiss-Wright Corporation and will be used with the J-65 Sapphire jet engine.

• **Jack & Heintz, Inc.** . . . The plant at Bedford, Ohio, which was leased last July, was taken over in November by the firm. Full production is scheduled for late next year.

• **The M. W. Kellogg Company** . . . The construction of Chili's first refinery will begin in about a year under the direction of a Kellogg subsidiary, Kellogg Pan American Corporation. This $10,000,000 plant, to be located roughly 10 miles north of Valparaiso, will produce products such as liquefied petroleum gases, motor gasoline, tractor gasoline, kerosene, two grades of diesel oil, and heavy fuel oil.

• **Lear, Incorporated** . . . A school for instruction in the theory, installation, and service of the Lear L-2 autopilot was established for the month of September, 1951, at the Grand Rapids, Mich., plant. Every distributing organization was invited to send a technical representative to the school at which housing, meals, and instruction were provided gratis by the company for the entire period . . . Among the personnel changes are the appointment of A. G. Handschumacher, Vice-President, as General Manager of the Grand Rapids, Mich., Division and of W. Dawkins Espy, Vice-President, as Chief Engineer for the

Grand Rapids Division . . . The Board of Directors has appointed an Executive Committee that is composed of the following: Kenneth MacGrath, a Director of Lear and Vice-President of Whirlpool Corporation; Richard M. Mock, A.F.-I.A.S., President of Lear; and Paul Moore, Executive Vice-President and General Manager of Lear. At the same time, Mr. Moore was elected to the post of Treasurer.

• **Lockheed Aircraft Service, Inc., Subsidiary of Lockheed Aircraft Corporation** . . . J. J. Arostegui has been elected Assistant Treasurer of L.A.S. and its subsidiaries.

• **Lockheed Aircraft Corporation** . . . An engineering-training program has been instituted which calls for job rotation where feasible, expanded on-the-job training, and company underwriting of half the tuition costs for outside courses. The program will be company-administered.

• **The Glenn L. Martin Company** . . . A type certificate was awarded by the C.A.A. for the Martin 4-0-4 twin-engine air liner on October 5 . . . The Government-owned Plant 2 is gradually being taken over by the company, and it is expected that by early next summer Martin will occupy the entire 1,449,375 sq.ft. of the plant.

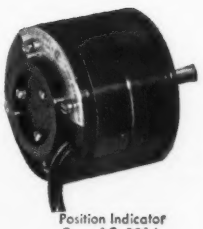
• **McDonnell Aircraft Corporation** . . . Construction of a new $3,500,000 flight test hangar has been started at St. Louis with completion expected in the fall of 1952.

• **North American Aviation, Inc.** . . . An F-86D Sabre flight simulator was designed and built for North American by the Engineering and Research Corporation. The trainer has been called the Sabre "Flightronic" by Erco . . . Two new versions of the Sabre, the F-86F and the F-86H, have been ordered by the U.S.A.F. The F-86F will be produced at the company's Columbus, Ohio, Division; the F-86H will be manufactured in Los Angeles. Production on the "F" model is scheduled for early in 1952, with the "H" model to follow within a few months at Los Angeles.

• **Pan American World Airways, Inc.** . . . The external paint scheme for its clipper fleet has been revised to include white tops and larger lettering. Company initials have been painted on the tail of the Boeing Stratocruisers in letters 3.5 ft. high. The license numbers have been done in 22-in. figures; the full company name has been placed the length of the fuselage in letters 15 in. high.

• **Phillips Petroleum Company** . . . The 1951 Award for Chemical Engineering Achievement was presented to Phillips on November 28 during the biennial Exposition of Chemical Industries in New York. The award was won for work in developing high-abrasion carbon black and for major contributions to the success of cold rubber. The magazine, *Chemical Engineering*, sponsored this award to the company making the most important chemical engineering contribution since January, 1948.

• **Pratt & Whitney Aircraft Division, United Aircraft Corporation** . . . The construction of an additional 180,000 sq.ft. of manufacturing area, plus office space, locker rooms and a cafeteria has been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MICROSYNS

The Doelcam Microsyn is an electro-magnetic four pole, reluctance bridge unit providing rugged construction, inherent electrical and mechanical simplicity, and high accuracy performance in the following applications:

Position Indicator — provides an electrical indication of angular displacement with high signal-to-noise ratio.

Stiffness Motor — operates as a torsional spring with adjustable stiffness coefficient.

Torque Generator — supplies a torque proportional to excitation and independent of shaft rotation.

Variable Inductor — offers an inductance that varies linearly with shaft rotation.

The Doelcam Microsyn can be designed for special applications in a wide variety of sizes. Units are available in instrument housings or as rotor and stator combinations to provide for individual mounting.

For more details, write to:

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OHIO K-S *disposable*
OXYGEN MASK
FOR OXYGEN ALTITUDE
X-C FLIGHTS

Now, OHIO offers a lightweight, inexpensive oxygen mask that can be discarded after use by one passenger. The new K-S Disposable Oronasal Oxygen Mask is

LIGHTWEIGHT
Clear, transparent plastic
SANITARY
Worn, then discarded
COMFORTABLE
Pliability insures pressure-free fit
EFFICIENT
Usable with any oxygen system

USE IT! DISCARD IT!
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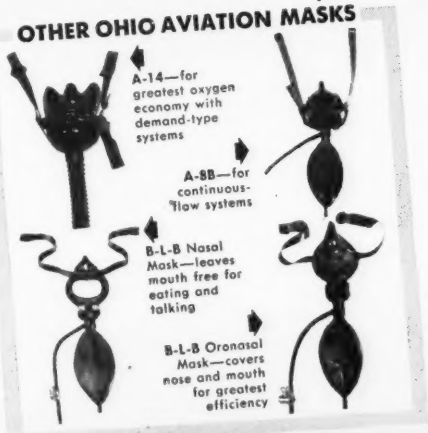
OTHER OHIO AVIATION MASKS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A-8B—for continuous-flow systems
B-L-B Nasal Mask—leaves mouth free for eating and talking
B-L-B Oronasal Mask—covers nose and mouth for greatest efficiency

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When the steady hand of Experience is a Must . . .

Every cut must be *right* in transforming a diamond such as the fabulous Jonkers from a rough stone into gleaming, perfect jewels. Today, the famous gem cutters of Holland remain unexcelled in this exacting work, for it demands a combination of *skill* and *knowledge* that can only come with long experience. These are the ingredients of greatness, and wherever they are found, in the arts or in industry, the result is much the same. In aviation for example, Eclipse-Pioneer's leadership dates back to the earliest days of the industry. No matter what your problem in the design or production of dependable instruments and accessories for your planes, you will find the answer at Eclipse-Pioneer. Whether it is a problem of pure development, or the mass production of a proven design, you are always backed by the steady hand of experience when you call on Eclipse-Pioneer.

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TETERBORO, NEW JERSEY

Export Sales: Bendix International Division, 72 Fifth Avenue, New York 11, N. Y.

started in East Hartford, Conn. It is being built adjacent to the Hamilton Standard plant, just south of the main Pratt & Whitney plant. Present plans call for Pratt & Whitney's taking over both the new addition and the present Hamilton Standard plant next spring when the Hamilton Standard Division moves to its new Windsor Locks plant. The space will be used to manufacture jet engine parts. Pratt & Whitney has another construction project going on at North Haven . . . A booklet on the "Pratt & Whitney Vertical Millers and Profilers" is available gratis.

• **A. V. Roe Canada Limited** . . . Early developmental work is being conducted on an improved version of the CF-100 all-weather jet fighter, which will be known as the CF-103. According to reports, it will have sweptback wings and will be powered with a "super" Orenda engine. CF-103 production is scheduled for late 1953. Work is also being done on a new version of the CF-100, designated the Mark IV, which is scheduled to fly in the early part of 1952. The Mark IV, it is said, features a more powerful Orenda engine and improved radar and armament . . . An Orenda-powered CF-100 fighter was officially presented to the Royal Canadian Air Force during ceremonies held on October 17 at Avro Canada's plant . . . Crawford Gordon, Jr., has been appointed President and General Manager. He succeeds Walter N. Deisher, Vice-President and General Manager, who retired due to ill health. The former President, Sir Roy Dobson, has assumed the post of Chairman of the Board, thus filling the vacancy left by the recent death of J. P. Bickell.

• **Scintilla Magneto Company, Bendix Aviation Corporation** . . . Separate aviation and industrial sales departments have been organized.

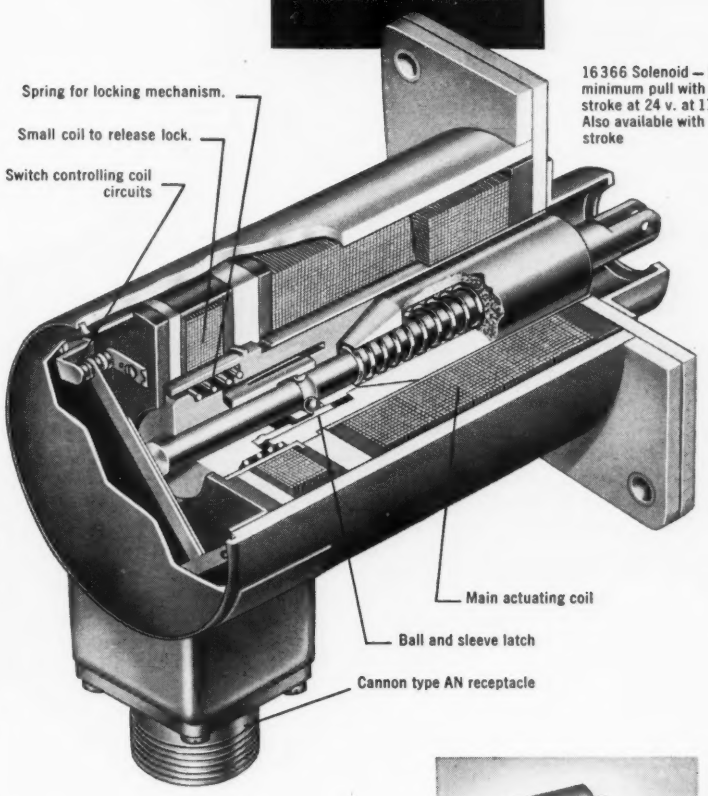
• **Servomechanisms, Inc.** . . . The following executive appointments have taken place in the Westbury, L.I., Fort Lauderdale, Fla. and Los Angeles, Calif., divisions: J. A. Granholm, formerly treasurer, is now Executive Vice-President; C. H. Rodgers, formerly Controller, has been appointed Treasurer; Eugene W. Kulesh, A.M.I.A.S., formerly General Manager, has been appointed Divisional Vice-President in charge of the Florida division; H. R. Larsen, formerly Manager of the West Coast division, has been appointed Divisional Vice-President.

• **Solar Aircraft Company** . . . Two hundred versions of ceramic coatings for metals in both the low- and high-temperature range have been developed at Solar. The exclusive license to manufacture, market, and service these Solar-developed coatings has been given to Ferro Corporation.

• **Trans World Airlines, Inc.** . . . The line's twenty-fifth birthday will be celebrated this coming May 21. T.W.A., whose first Skyliner flew to Paris from Washington, D.C., in December, 1945, received its international certification 6 years ago . . . Thomas K. Taylor has been advanced from Assistant Vice-President to Vice-President. Mr. Taylor will continue to be based in Washington, D.C. . . . Clarence E. Fleming, Vice-President of the

Here's why those in the know

—demand **CANNON SOLENOIDS**

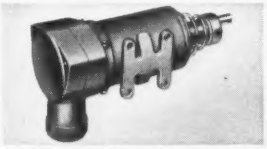

16366 Solenoid—18.7 lb. minimum pull with 1/2" stroke at 24 v. at 170°F. Also available with 1-1/6" stroke
Spring for locking mechanism.
Small coil to release lock.
Switch controlling coil circuits
Main actuating coil
Ball and sleeve latch
Cannon type AN receptacle

Here's a special purpose Cannon D.C. Solenoid, #16366 for aircraft. Design and safety conditions require that the armature lock in the actuated position for an indefinite time, without relying on a continuous flow of current.

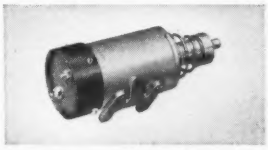
The ingenious ball-and-sleeve latch locks the armature as the main coil circuit is broken through the built-in switch. When current is applied to the smaller coil, motion of the sleeve releases the main armature. Study of the drawing shows how a smooth-acting, positive lock is accomplished.

This is one of more than 60 different Cannon D.C. Solenoids built around 18 basic coils for either continuous or intermittent service. Write for Solenoid Bulletin free on request.

#1154 an intermittent service solenoid, 12v, D.C.—10.5 amps.—stroke 9/32", weight 13 oz.



#4440 a continuous service solenoid, 24v, D.C.—3.6 amp. (starting) .42 amp. (holding)—stroke 3/8" weight 16 oz.



11790 a continuous service solenoid, 24v, D.C.—3.6 amp. (starting) .42 amp. (holding)—stroke 3/8" weight 15.5 oz.

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company since 1942, resigned as of October 15.

• **Westinghouse Electric Corporation** . . . In a move to expedite the defense activities, two vice-presidents have been assigned to new duties. L. E. Osborne was moved from Vice-President in Charge of Manufacturing to the newly created post of Executive Vice-President—Defense Products. Tom Turner, who was Vice-President in Charge of Labor Relations, retains that post and, in addition, assumes Mr. Osborne's former duties. Mr. Turner's new title is Vice-President in Charge of Manufacturing and Labor Relations.

• **Wright Aeronautical Division, Curtiss-Wright Corporation** . . . Wright Aeronautical Corporation has merged with Curtiss-Wright Corporation . . . W. G. Lindquist, Chief Engineer, was elected a Vice-President of the company.

I.A.S. Sections

Baltimore Section

M. Francis Taylor, *Secretary*

The thirty-second meeting of the Baltimore Section was held on October 16 at The Johns Hopkins University. The Chairman, Mr. Jewett, called the meeting to order at 8:35 p.m. There were approximately 75 members and guests present.

The speaker was Col. J. F. Taylor, Deputy for Air Defense Command Systems, Research and Development Command, U.S.A.F. Colonel Taylor, who was until recently Chief of the All Weather Division at Wright Air Development Center (Wright-Patterson Air Force Base, Ohio), spoke on the "Operation of the U.S. Air Force Research and Development Command" with emphasis on why the systems concept in aircraft development is so important.

The speaker introduced his presentation by stressing the change in American concept of how best to succeed in a major conflict. He pointed out that in World War I, success was obtained both by overwhelming the enemy and by outsmarting them; that in World War II it was primarily a matter of overwhelming them; and that, today, it may be a physical impossibility to overwhelm the hundreds of millions that may be aligned against us. The establishment of the U.S.A.F. Research and Development Command was a direct result of the necessity to outsmart any aggressor. The function of the A.R.D.C. is to ensure that we do so in the air by means of having technical superiority.

Colonel Taylor recounted the old story of the airplane designer who flew in his latest "pursuit" for Air Force evaluation. It performed well, and when at last someone asked, "Where are the guns?" the designer replied, "Oh, we'll find a place for them somewhere." Today, we take it for granted the aircraft will fly, that it will be controllable, that it can be fast, and that it can go far. The problem is one of ensuring that the aircraft is the proper integral part of a system that can succeed.

The facilities available to the A.R.D.C. include: (1) A.F. Cambridge Research Center, Mass.—specializing in basic research; (2) Rome Air Development Center, N.Y.—electronic testing and application of the Cambridge data; (3) A.F. Missile Test Center, Fla.—long-range missile testing; (4) Wright Air Development Center, Ohio—airframe and power-plant development; (5) Arnold Engineering Development Center, Tenn.—aerodynamic research; (6) Holloman Air Force Base, N.M.—missile testing; and (7) A.F. Flight Test Center, Calif.—aircraft testing.

Through the direction, coordination, and cooperation of these facilities, the A.R.D.C. develops aircraft or missiles that will have proper armament; will fly in all climatic conditions; will have the electronic gear, equipment, and other features that are necessary; and will be available when needed to complete the defense system established.

The speaker cited the great need for coordination by pointing out that in some cases it may be necessary to order equipment for an aircraft before ordering the aircraft itself in order to get the complete plane on time. He also stressed the benefits to be derived through service-industry cooperation in development and testing.

Colonel Taylor closed his presentation by pointing out that the A.R.D.C. is concerned with an airplane from its inception to the end of its service life and that most of our design progress is by evolution rather than by revolution.

The meeting was adjourned at 10:00 p.m.

Cleveland-Akron Dinner Meeting: *Shown at the speaker's table at the October 23 meeting of the Cleveland-Akron Section are: (left to right) Don Welty; Gen. F. R. Hopkins; the former governor of Ohio, Thomas Herbert; Sam Mullin; E. W. Cleveland (standing); J. H. Collins, Jr.; Dr. R. Ross; Dr. E. R. Sharp; and Robert Cass, speaker of the evening.*

Chicago Section

Alfred F. Stott, *Secretary*

The Chicago Section opened its 1951–1952 year on October 4, when 156 members and guests assembled for dinner at the Museum of Science and Industry on the south side of Chicago. Each one present enjoyed a wonderful roast beef or chicken dinner. Following the dinner, guides from the museum conducted the group on a tour of the nuclear energy and radar exhibits.

At 8:00 p.m., approximately 285 members and guests gathered in the small auditorium for an excellent talk on "Nuclear Engines for Aircraft" presented by Dr. Miles C. Leverett. Dr. Leverett, who was Technical Director for the NEPA Division of Fairchild Engine and Airplane Corporation, continued his association with the NEPA project when it was taken over last spring by the Aircraft Gas Turbine Divisions of General Electric Company.

The meeting was called to order by Chairman Robert H. Wendt, who welcomed all present. He introduced the various committee chairmen, including Dr. H. L. Hull, the Program Chairman, who in turn introduced the speaker of the evening.

Dr. Leverett's full paper is contained in this issue and may be found on page 29.

Cleveland-Akron Section

Harrison C. Chandler, Jr., *Secretary*

The first meeting of the 1951–1952 year, held on October 23, had as its principal feature a paper by Robert Cass, Assistant Administrator of the

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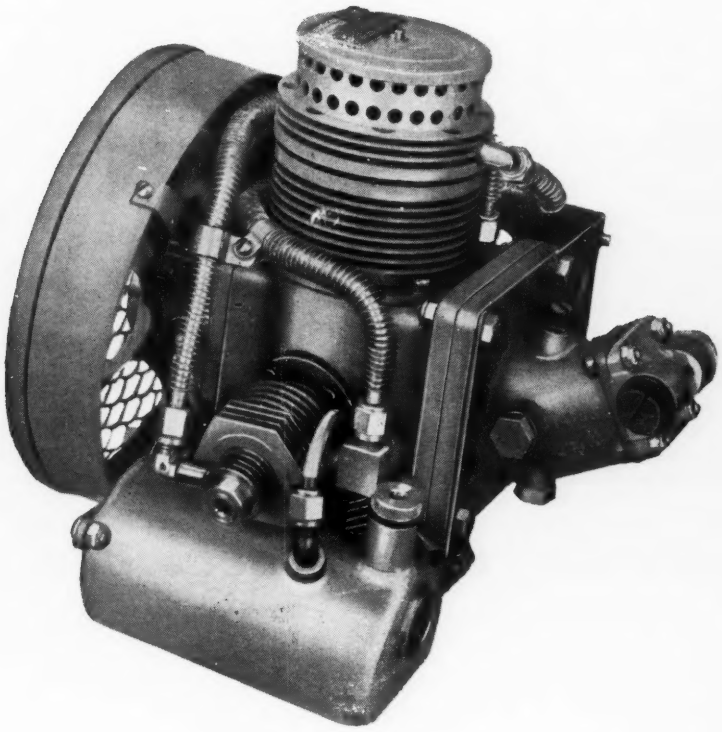

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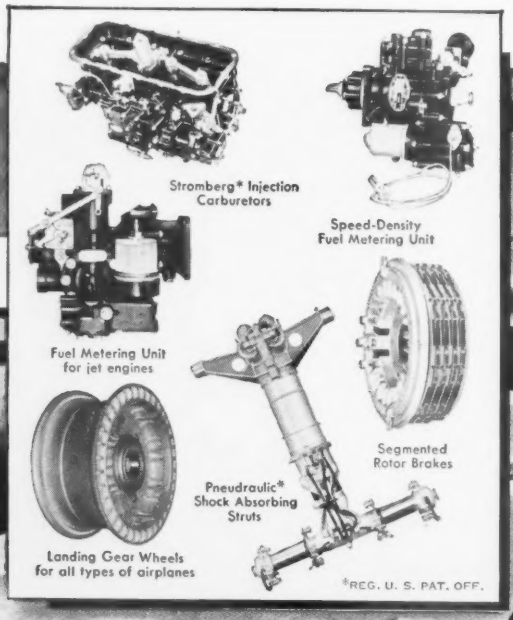
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Motor Vehicle Division, National Production Authority, on the subject, "Strategic Materials."

A record turnout of 265 members and guests attended the dinner, with some additional members arriving later to swell Mr. Cass' audience. The guests included former Governor of Ohio, Thomas Herbert. The meeting was held at the Cleveland Pneumatic Tool Company. The evening's program included tours through the plant, a social hour, dinner, and the paper by Mr. Cass. E. W. (Pop) Cleveland, Section Chairman, presided at the meeting.

Mr. Cass indicated in his paper that he considered it appropriate to speak before engineers and scientists of the aviation and automotive industries because these two industries together account for 40 to 50 per cent of all consumption of materials, both strategic and otherwise, and, hence, are the largest users of materials. He listed steel, copper, and aluminum as the only controlled materials.

Steel production capacity is increasing, and by 1952 this country will have 40- to 50-million ingot tons more steel capacity than at present, Mr. Cass said. This increase will equal the present total steel output of Great Britain. Stainless steel will continue to be in seriously short supply for a long time to come, however, because of the difficulties in procuring the essential alloy elements.

Manganese, one of these materials, must be imported from such countries as Russia, India, and Latvia. Because of this situation, it is important that sea lanes be protected.

Procurement of nickel for vital defense applications is a problem of top importance now being discussed in Washington, according to Mr. Cass. Fortunately, 90 per cent of the supply is found within the continent of North America. The sharply increasing military demands for nickel will necessitate a continuing trend to reduce the allocation of nickel for civilian applications.

Boron may conceivably replace nickel somewhat as an alloy with steel, and thus help to alleviate the problem caused by the demand for nickel. Mr. Cass indicated that the magnitude of this trend will depend directly upon the ingenuity exercised by scientists and engineers. India is one of the principal sources of boron.

Mr. Cass stated that the United States now imports copper at the rate of 500,000 tons per year. The Belgian Congo is one of the large sources of this material. The problem of future supply of copper is regarded as serious, because there is no immediate prospect for either increasing or maintaining the present rate of supply. A stockpile of 6,000,000 tons which existed in January, 1950, has been entirely expended. As a result, it is becoming necessary to reduce the amount of copper used in the automotive industry.

Tungsten must also be imported. China is the principal source of supply, and, with the present world conditions, the problem of obtaining this material becomes increasingly difficult. Lead is now being imported at the rate of 200,000 tons per year. Stockpiles of lead are low. Other materials discussed included tin, columbium, and titanium. A formidable obstacle to further use of titanium, regarded as a possible replacement for columbium in alloy steels, is its present high cost—about $25 per pound.

Aluminum provides the one bright spot in the otherwise dark picture regarding strategic materials. A 90 per cent expansion in aluminum capacity is in prospect, so that early in 1952 this country should have an adequate supply for both defense and civilian needs. The automobile industry is already making long-range plans to expand the use of aluminum in such parts as generators, cables, radiators, and other parts.

The officers of the Cleveland-Akron Section for the 1951–1952 year include: Chairman, E. W. Cleveland; Vice-Chairman for Cleveland, Lewis A. Rodert; Vice-Chairman for Akron, Morris A. Zipkin; and Secretary-Treasurer, Harrison C. Chandler, Jr.

Dayton Section

Charles L. Hall, *Secretary*

The first meeting of the season was held at the Biltmore Hotel on September 26 with approximately 60 members and guests present. The section was honored to have as its guest Lawrence D. Bell, President, Bell Aircraft Corporation. The speaker for the evening was Dr. R. C. Dehmel, Electronics Division, Curtiss-Wright Corporation, who spoke on the "Aircraft Flight Simulator."

Dr. Dehmel described the flight simulator as a grounded aircraft in which the engines, wings, control surfaces, and gears have been replaced by electronic computors. These actuate instruments and pressurize the cockpit in the same fashion as in actual aircraft under flight conditions. The simulators, which were developed by Curtiss-Wright under Dr. Dehmel's supervision, are in operation by the Air Force, Navy, and air lines. Dr. Dehmel points out that men who train in simulators are not there to learn to fly. The instructor on the flight simulator can produce some 85 different kinds of trouble. He can start fires; fail instruments; ice the wings, propellers, and carburetors; lock controls; disable radio facilities; and in short, make the crew "sweat out" the solution for just about every accident experienced. Dr. Dehmel stated that a Flight simulator for a four-engined aircraft contains more than 228,000 parts and 95,000 ft. of wire.

▶ The Dayton Section held its second meeting of the season at the Wright-Patterson Air Force Base on October 31. A group of 75 members and guests enjoyed a turkey dinner in the Senior Officers Mess and then adjourned to the Aircraft Laboratory area where a tour of four wind tunnels was made.

The wind-tunnel tour was directed by Col. Jack Gibbs, Chief of the Aircraft Laboratory, Wright Air Development Center, and his assistant Lieutenant Colonel Howel, Chief of the Wind Tunnel Branch. An excellent film on wind tunnels was shown before the tour started. The group inspected the large 20-ft. tunnel, the vertical tunnel, and two supersonic tunnels, all of which were in operation.

Hagerstown Section

Robert A. Darby, *Secretary*

The annual social meeting was held on September 25 at the Fountainhead Country Club, starting the 1951–1952 season with the installation of the new officers. Robert D. Gilson, retiring Chairman, presided and, at the conclusion of the dinner, introduced the new officers: Chairman, Earl E. Morton; Vice-Chairman, E. R. Gelvin; and Secretary-Treasurer, R. E. Braus.

After the introductions, three films were shown: *Southern Pine Maneuvers*, with eye-witness comment by Walter Tydon; *Canadian Ore Lift*, with comment by Mr. Gelvin who participated as pilot of the C-119 airplane used; and *Jet Fighter Manufacture and Operations*, a Republic Aviation picture.

The second film showed the C-119 operations during 2 months of the past summer in which, under U.S.A.F. auspices, over 2,000,000 lbs. of construction machinery and equipment were flown with a single C-119 into the new Ungava ore field in northeastern Quebec and Labrador. This equipment is now being used in the construction of a 360-mile railroad that will connect the mines with civilization. Typical loads were power shovels, tractors, scrapers, trucks, air compressors, bridge timbers, and 48-in. culvert pipe. The heavier items were sectionalized into loads generally not exceeding 20,000 lbs. The film was a most encouraging picture of the amazing usefulness of the cargo airplane in construction work.

The meeting was attended by 79 members, wives, and guests.

Hampton Roads Section

George White, *Outgoing Secretary*

As the result of an election of officers of the 1951–1952 year, the following men have assumed office: Chairman, Mel-

vin N. Gough; Vice-Chairman, John A. Harper; Treasurer, Herbert H. Jackson; Corresponding Secretary, Jesse L. Mitchell; and Recording Secretary, Albert L. Braslow.

Los Angeles Section

Milton A. Miner, *Secretary*

Dr. Leo Schapiro, Metallurgical Engineer, Santa Monica Plant, Douglas Aircraft Company, Inc., talked to the September 6 specialists' meeting on the subject, "Tomorrow's Metals for Aircraft."

On September 12, a second specialists' meeting was held, the subject being, "Pulse Width Modulation—Frequency Modulation Telemetering." It was presented by John R. Kauke, Research Engineer, Equipment Group, Santa Monica Plant, Douglas Aircraft Company.

▶ On September 20, Adm. John W. Reeves, Jr., U.S.N., addressed a dinner meeting on "Air-Sea Power." Since his retirement in 1950, Admiral Reeves has been the Manager of Los Angeles International Airport. He began his talk by pointing out that competition between the various branches of the service is as desirable as it is in other phases of our national life. He believes that the average citizen must take a strong and active interest in our military policy or the military leaders and the politicians may bankrupt us.

Basically, Admiral Reeves holds that the airplane is just one more weapon, a potent one, in the military arsenal. It does not alter tactics of exploiting mobility, flexibility, and surprise attack.

No potential enemy of the United States has an appreciable air-sea power. Some ask, "Why should we?" Admiral Reeves answers this by outlining the following advantages: Assuming that an enemy would occupy most of Europe, air attacks on us would require aircraft with 3,500- to 4,500-mile combat radii. Such range is possible only with large and rather slow bombers. First-line fighters can not be built at present with such a range. Even if 70 per cent of an attacking force gets through to a target, as some experts predict, Admiral Reeves reminds us that nothing over 10 per cent attrition can long be supported; this is based on our World War II experience. In the last war, night fighters using radar were in their infancy. Even so, effective interception of enemy aircraft was possible, especially in the South Pacific, against Japan.

Since we can ill afford a stalemate in Europe, we must mount a stronger air attack than our enemy. An air attack can not defeat an enemy, as demonstrated by Korea, but Admiral Reeves believes that a strong combination of land and sea-air power can win a major decision.

Carrier teams can protect, maintain, and service aircraft from the fastest fighters to long-range bombers. A carrier task force becomes a mobile air base at sea, capable of staying in service for long periods of time, since it can be supplied continuously.

A carrier force is not highly vulnerable to "A" bomb attack, according to the speaker, since individual ships are widely dispersed while at sea, and only a single major ship could be destroyed with a single bomb. Even though they are spread out over 10 to 15 miles, the task force operates as a closely controlled unit. With a cruising speed of some 30 knots, a great mobility of the unit permits coverage of any part of a 2,000-sq. mile area by the ships plus their planes. Further, repeated attacks can be carried on around the clock.

A great-circle bomber attack on Russia might be made over the Arctic, but operational problems in the extreme cold are severe. Any other course would permit our stationing aircraft carriers along the route to refuel and give fighter escort to the bombers and to intercept enemy aircraft. Further, our carrier forces can carry the attack directly to the enemy. The great mobility of such a force has many obvious advantages over fixed land bases.

Admiral Reeves states that plane for plane, the carrier-based unit can deliver five times the bomb load of the land-based unit. In a hypothetical case with a land base 3,500 miles from an enemy target, the carrier aircraft can deliver 35 times the bomb load of land-based airplanes.

The threat of submarine attack on the carriers will probably soon be capable of control by new developments in anti-submarine warfare.

To conclude his talk, Admiral Reeves pointed to the great advantages of carrying the fighting over enemy territory, which the United States can force with a strong superiority in air-sea strength. Therefore, he urgently supports a strong air-sea force in our military planning.

Montreal Section

H. V. Braceland, *Secretary*

The Chairman of the Montreal Section, E. B. Schaefer, opened the first meeting of the 1951–1952 season on October 10 by stating that an interesting year lay ahead. A complete program had been prepared by the Program Committee, and he stated that our future meetings would be held at the Mess of 401 Fighter Squadron, City of Westmount, on Sherbrooke Street. He also stated that bar facilities would be made available after the meetings.

Mr. Schaefer then introduced the guest speaker, John Orr, of the National Research Council, Ottawa. Mr. Orr's subject was "Recent Developments in Aircraft De-Icing."

It was evident from Mr. Orr's material and method of presentation that he is not only an authority, but a master of the subject. He generalized and discussed the various methods of aircraft anti-icing and deicing principles, pointing out the advantages and disadvantages of each. He stated that his paper would stress electrothermal deicing since most of his research work had been conducted in order to develop electrothermal deicing. To establish a satisfactory method, considering weight, power, and economy, it was considered that electrothermal methods offered the best approach.

The effects of ice and icing conditions were next discussed. Mr. Orr detailed the hazards of power-plant and aircraft icing. Similarly, the types of ice and ice formations were noted. Mr. Orr stressed the fact that the adhesion qualities of ice were the biggest problems when considering deicing.

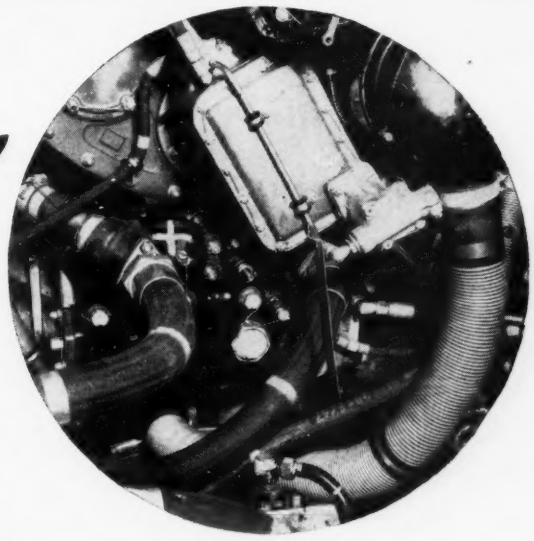
Slides showing the research equipment including test apparatus measuring devices, wind tunnel, etc., were shown. Mr. Orr indicated the necessity of such equipment and the specific uses each unit had.

Meteorological aspects were next considered. Here, the speaker showed the need for some method of measuring ice formation in flight. Slides were again shown which indicated clearly the progress that has been made in developing accurate methods of measuring temperature, water content, etc., and, in general, all natural elements or phenomena that make icing possible.

Mr. Orr then explained the requirements for thermal deicing with regard to the heat required to maintain proper deicing under adverse weather conditions. It was estimated that the heat for convection, evaporation, and water heat on the leading edge of a wing were of equal B.t.u.'s at approximately 200 m.p.h. Beyond 400 m.p.h., the heat of air compression was sufficient to overcome convection and evaporation. It was estimated that the power required for aircraft prop deicing was approximately 8 watts per sq.in.

It was estimated by Mr. Orr that electrothermal icing for complete aircraft including props would weigh approximately 500 lbs.

The icing problems of jet engines were explained, and Mr. Orr outlined the various tests that had been conducted by his laboratory. The following points were noted with regard to the above: (1) screens in the intake system of a jet, or anywhere else, are hazardous; (2) there is no trouble from ice formation beyond the third stage in an axial



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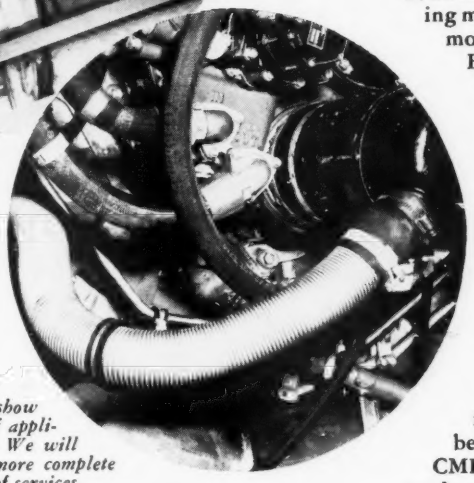

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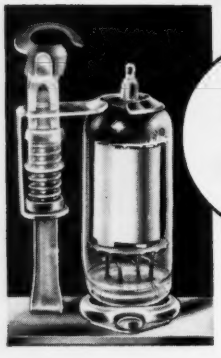

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compressor; (3) methods of deicing for jets together with advantages and disadvantages are as follows: (a) chemical or pastes (distribution of alcohol); (b) exhaust heating; and (c) surface heating by electrothermal and magnetic methods.

Mr. Orr ended his paper by repeating the story of the eight F-94's that crashed due to icing conditions and stressed the importance of a program for development on ice prevention.

Mr. Schaefer called upon Peter Gooch to express a vote of thanks to the speaker.

The Chairman then adjourned the meeting.

New York Section

F. K. Teichmann, *Secretary*

The New York Section held its first meeting of the 1951–1952 season on September 27 in the Engineering Societies' building.

The meeting was devoted to a symposium on the highlights of the Third Anglo-American Aeronautical Conference held in Brighton, England.

William F. Milliken, Jr., Manager, Flight Research, Cornell Aeronautical Laboratory, Inc., led off the symposium on aerodynamics; Robert W. Rummel, Chief Engineer, Trans World Airlines, devoted his remarks to air transport; and Dr. N. J. Hoff, Professor and Head, Department of Aeronautical Engineering, Polytechnic Institute of Brooklyn, discussed the various papers on structures. Jerome Lederer, Director of the Daniel and Florence Guggenheim Aviation Center, Cornell University, spoke on safety. His remarks were accompanied by slides showing various British practices.

C. E. Pappas, of Republic Aviation Corporation, presided at the meeting attended by about 75 people.

Philadelphia Section

Emily D. Rogers, *Secretary*

The October 3 meeting was held at the Engineers' Club. The speaker was Capt. John. R. Poppen, Director of Aviation Medicine, Acceleration Laboratory, Naval Air Development Center, Johnsville, Pa. Captain Poppen was recently elected President of the Philadelphia Branch of the Aero-Medical Association. He has been a Flight Surgeon since 1922 and has long been recognized as one of the leading authorities in the field of aviation medicine. In the field of research, Captain Poppen did the original work on the physiological effect of acceleration g forces on pilots in aircraft. In his present position, he is directing the construction of the new human centrifuge

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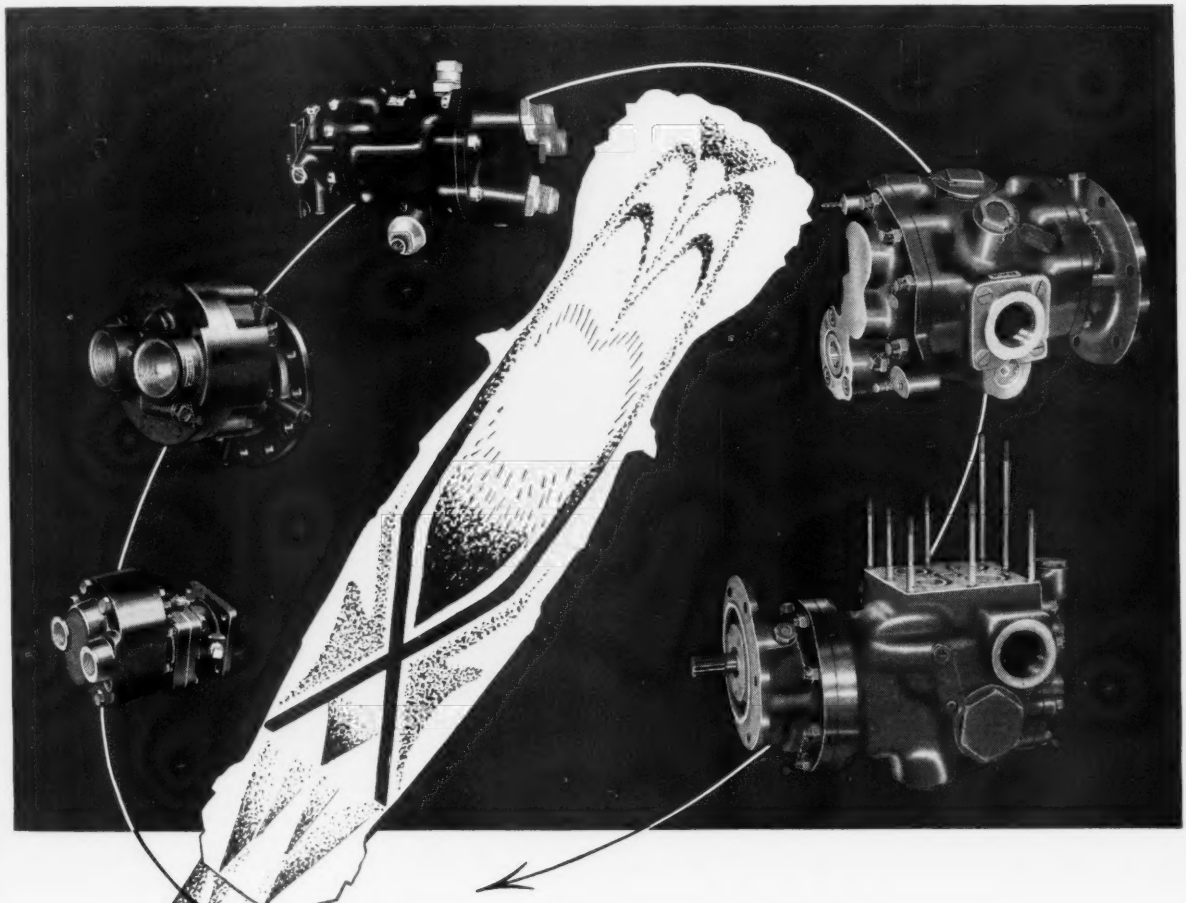

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The title of Captain Poppen's talk was "Acceleration Forces of Physiological Import." He discussed the various accelerations that are placed upon the pilot during high-speed maneuvers, in the course of being ejected from a high-speed aircraft, and in a crash. He explained the physiological effect on the pilot, the limits of human endurance under these operations, and means of alleviating or mitigating the harmful effect of acceleration in maneuvers and crashes.

San Diego Section

H. L. Braasch, *Secretary*

A dinner meeting was held at the San Diego Hotel on September 6. The dinner was followed by an interesting talk given by Lt. Col. S. P. Dillon, Officer-in-Charge of all Air Force Contracts in the San Diego area. The subject of the talk was "Development of Strategic Bombardment Aircraft."

Colonel Dillon is a long-time B-36 pilot and former Chief of Air Force Flight Operations at Consolidated Vultee Aircraft Corporation's Fort Worth Division. In his present position, he has personally test flown most of the B-36D's so far delivered from Convair, San Diego. During World War II, he was a B-17 pilot in England and North Africa. He holds the D.F.C., Air Medal with nine Oak Leaf Clusters, and the Army Commendation Ribbon with one Oak Leaf Cluster.

Although Colonel Dillon's talk centered primarily around the B-36, it covered the entire development of bombardment aircraft from the B-17 on through the B-52 and B-60. For reasons of security, little information was discussed regarding the B-52 and B-60 airplanes. Graphs and charts were used to supplement the talk. One thing that was noticeable by inspection of the graphs was the large gap that occurred between the reciprocating-engine aircraft and the turbojet aircraft; this gap would have normally been eliminated by the turboprop aircraft. Another point that was stressed was the necessity for allowing the necessary "lead" time between the original design of a bomber and the date at which it can be produced in large quantities.

Following the talk, a movie, *Target Peace*, was shown. This is a short made by Convair and deals with the development of the B-36.

The new officers of this section are: Chairman, W. C. Heath; Vice-Chairman, R. P. White; Treasurer, N. E. Maxwell; Recording Secretary, J. G. Wenzel; and Corresponding Secretary, H. L. Braasch.

▶ The San Diego Section held a dinner meeting on October 5. A short business session preceded the main talk. R. P. White, the new Vice-Chairman of this section, presented W. T. Immenschuh with the retiring chairman's key. Mr. Immemschuh expressed his sincere appreciation for the presentation and stated that he had looked forward for several years to this award. The new officers were introduced by D. H. Bennett, Area Councilor Nominee.

Following the business session, an interesting talk on "Supersonic Research at the Naval Ordnance Laboratory" was given by Dr. George L. Shue, Chief, Aerodynamics Section, Naval Ordnance Laboratory, White Oaks, Md. Prior to accepting his present position in 1947, Dr. Shue worked for Consolidated Vultee Aircraft Corporation and contributed extensively to the advanced and confidential research work in the field of compressible gas dynamics. His talk was supplemented by slides showing research and development in supersonics at the Naval Ordnance Laboratory.

The Bureau of Ordnance has three supersonic wind tunnels. It was pointed out that the Bureau of Ordnance has perhaps been interested in supersonic aerodynamics longer than either the Bureau of Aeronautics or the Air Force. The Naval Ordnance Laboratory at White Oaks has two flight ranges (tubes) for testing free-flight models. The results of a flight are recorded by the use of 25 photographic spark stations along the range. One of these ranges is pressurized. Mediums other than air (bromine and freon) are used effectively to lower the speed of sound and thus increase the Mach Number.

Since Dr. Shue has recently returned from a tour of England, he gave a brief report of impressions gained. Although the British lack good wind tunnels, such as we have, Dr. Shue felt that their airplane designs were excellent. They have many different prototype airplanes although few are in production.

St. Louis Section

Robert A. Killoren, *Secretary*

The October 16 meeting was held at the Engineers' Club and was attended by 80 members. David Lewis presided in the absence of the retiring Chairman, Don Berlin. Following the reports of the Secretary and Treasurer, Edward Barker presented the slate of nominees for 1951–1952 as chosen by the nominating committee.

The new officers were elected and introduced as follows: Chairman, Carl J. Wenzinger; Vice-Chairman, John

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Noyes, Jr.; Secretary, Robert A. Killoren; and Treasurer, Ben G. Bromberg. Three members of the Advisory Board were elected as follows: Edward M. Flesh, Herbert R. Grummann, and Kendall Perkins.

The speaker of the evening was Kendall Perkins, Vice-President—Engineering, McDonnell Aircraft Corporation, who presented an informative report of his observations made while in England at the joint meeting of the I.A.S. and Royal Aeronautical Society.

After a brief introduction about England in general, Mr. Perkins reviewed some of the papers presented at the meeting. He described the results outlined at Brighton which were obtained by the use of "porous suction" to reduce profile drag and promote boundary-layer control. A few other papers were reviewed, and then the main part of the talk was devoted to a well-balanced discussion of the present English planes, both production models and experimental prototypes viewed at the Farnborough Air Show and to an evaluation of English and American aviation engineering and production.

The audience found the talk interesting and informative, especially the comparison of the two countries' aviation industries. This was evident by the numerous questions that followed.

Texas Section

R. Christy, *Secretary*

Members and guests of the Texas Section held a dinner meeting at the American Legion Hall in Grand Prairie, Tex., on October 25.

P. Alberti, Vice-Chairman, called the meeting to order and announced the plans for the coming election of officers. He in turn called upon P. Helweg and H. Marx, Nominating Committeemen, to explain the voting procedure and name the nominees from the Fort Worth and Dallas areas.

Guest speaker was Harold O. Adrion, Power Plant Test Engineer, Chance Vought Aircraft Division of United Aircraft Corporation. Mr. Adrion's subject was "The Principles of Turbojet Afterburning." He first explained how the various components of the turbojet engine contribute to the thrust. The temperature of the gases is increased by combustion of the fuel, and the resulting pressure energy is then transformed into velocity energy and then into thrust. This type of engine requires only one pilot-operated control to regulate the fuel flow, which in turn controls the r.p.m., while the propeller-driven engine requires two controls to regulate the r.p.m. and manifold pressure.

Mr. Adrion pointed out that the thrust could be augmented by means of an afterburner. The effect of the afterburner is to reduce the drag effect of the engine components, thereby increasing the available thrust. This is accomplished by increasing the pressure of the gases, combustion of additional fuel in the afterburner, and increasing the tailpipe area, so that the unit pressure on the projected effective area of the engine is constant. Since the projected area is increased, the number of pressure forces that produce thrust is also increased. This additional thrust is available within one or two seconds after the engine control has been advanced to the afterburner "on position." Due to high fuel consumption, afterburning is used only for short periods when maximum thrust is required.

The meeting was concluded by an energetic and enthusiastic question and answer session.

Washington Section

J. H. Sidebottom, *Secretary*

On October 2, the Washington Section was privileged to have a prominent supersonic pilot and the project engineer on several new supersonic aircraft speak on problems associated with the operation as well as the structural and mechanical design of high-speed aircraft.

William B. Bridgeman, Test Pilot for Douglas Aircraft Company, who recently established new altitude and speed records in the Douglas Skyrocket aircraft, spoke to the section on many of his personal experiences in flying the various Skyrocket and Skystreak aircraft. Mr. Bridgeman explained that violent lateral oscillation of the D-558-II Skyrocket characterized most of the supersonic flights made in the airplane. The oscillation, or roll, usually developed at the top of the climb, or the "pushover" as Bridgeman termed it, although it was also noticeable on a less-violent basis during parts of the climb.

The most violent roll occurred on the fifth D-558-II drop launch, when Mr. Bridgeman made a pushover at 0.25*g*. The wings dipped as much as 75° and the rate of roll was 86° per sec. Bridgeman had trouble controlling the plane and was forced to cut his rocket power. On this flight, Bridgeman was close to the highest speed he attained throughout the program.

The oscillation was partially damped by locking the rudder during the climb on subsequent flights (the plane was equipped with an override mechanism to permit unlocking the rudder for landing) and by increasing the *g* force during the pushover, Bridgeman said. However, the rolling was never completely eliminated throughout the test program. Bridgeman also said that the D-558-II, the world's fastest plane, is already obsolete, because its controls are inadequate for a test program of the sort he ran.

At times, he had the plane in a complete vertical bank at the completion of his speed run, but it would not turn. He was forced to keep the maximum permissible angle of attack during climb in order to hold the plane's speed down to Mach 0.85.

Much of the information concerning flight characteristics of the Skyrocket was presented publicly for the first time in Mr. Bridgeman's speech, which was followed by a color movie of the air launching, high-speed flight run, and landing of the rocket-powered Skyrocket. Bridgeman concluded his discussion with an indication that the use of rocket engines and the air launch for experimental flight test of supersonic aircraft is certainly one successful way of accomplishing a difficult task. His experience has revealed that the rocket power plant, handled correctly, is a dependable source of power and that air launching eliminates much of the difficulty encountered in take-off with an airplane full of alcohol, liquid oxygen, and hydrogen peroxide.

Stanley W. Smith, Project Engineer of the X-1 and X-2 supersonic planes, Bell Aircraft Corporation, described the many structural and mechanical problems that confront the designer as the speeds and altitudes are increased.

Foremost among these problems is a definite trend toward the use of wings having very thin cross section to reduce the incidence of buffeting that may be regarded as a function of wing thickness. This, of course, introduces problems of sufficient strength and rigidity. Smith stated that wings for the X-1 had a maximum thickness of 8 per cent of the chord, requiring a skin thickness at the wing root of over 0.5 in., using 75ST aluminum alloy as the structural material. In order to maintain good structural efficiency, these skins were machine tapered to approximately $\frac{1}{8}$ in. thickness at the wing tip. Similarly, the X-2 utilizes a wing skin of full hard stainless steel machine tapered from the root to the tip.

In addition to the torsional strength and rigidity problems, Mr. Smith outlined similar detail surface design difficulties that may be even more critical because of further reducing the total thickness available for structure. Changes in airplane trim encountered in passing through the sonic speed are much more extreme than in subsonic airplanes, and it has become necessary to utilize adjustment of stabilizer angle rather than trim tabs for longitudinal trim. He further explained the systems used for assisting the pilot in handling increased surface loads for small high-speed aircraft. It has become necessary to provide new and unusual sources for energy for this purpose, such as small

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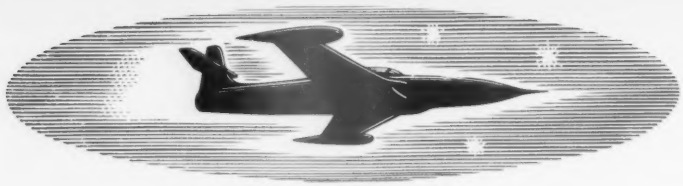

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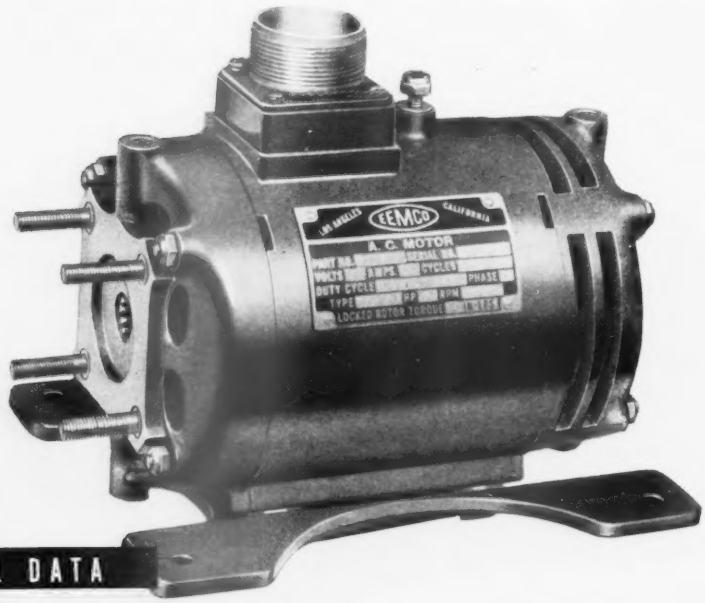

TECHNICAL DATA

Motor type:	3 phase, 400 cycle	Power Factor:	86.6%
Output:	2 h.p. continuous at 11,600 r.p.m.	Starting Torque:	20 in.-lbs.
Weight:	8.25 lbs. (8.82 lbs. including mounting plate)	Breakdown Torque:	Above 25 in.-lbs.
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high-speed gas turbines operated from the same propellants as those used for the rocket motor. In the case of the X-2, the source of power is a high-energy nickel cadmium battery, weighing approximately 300 lbs. and producing 8 hp. for one-half hour.

Smith also touched on the structural problems of propellant storage, the temperature differentials resulting from aerodynamic heating where the boundary layer may reach 1,000°F., and the many mechanical problems associated with producing a leak-proof air-conditioned pilot and instrument enclosure. He also mentioned the bail-out equipment for pilot ejection at high altitudes and high speeds, and the problem of fuel transfer from the tank to the motor requiring a propellant flow rate of nearly 600 gal. per minute through lines as large as 3 in. in diameter.

The meeting was concluded by the Honorary Chairman, F. B. Lee, Deputy Administrator, C.A.A., with an extensive question and answer period, during which time there was considerable discussion of the various features of the aircraft and piloting techniques employed in high-speed aircraft experimental work.

Wichita Section

Wilfred Pearce, *Secretary*

The results of an election of officers for the 1951–1952 year are as follows: Chairman, Henry F. Waring, Jr.; Vice-Chairman, Prof. Melvin H. Snyder, Jr.; Secretary, Wilfred Pearce; and Treasurer, Perry V. Row.

Student Branches

University of Alabama

Two films, *The Fleet That Came to Stay* and *Photography in Science*, were shown at the October 25 meeting. William E. Carr presided.

Cal-Aero Technical Institute

One hundred and fifty persons were present at the August 21 meeting to hear W. R. Custer, President, Custer Aircraft Corporation, speak on the "Custer Channel Wing." Chairman Charles Reid presided.

"Rocket Propulsion" was the subject on which Philip Albanese, Engineer, Rocket Development Group, North American Aviation, Inc., spoke at the September 26 meeting. Chairman Reid presided; 150 students were present.

Dr. Allen E. Puckett, Head, Missile Aerodynamics Department, Hughes Aircraft Company, spoke before the 130 persons attending the October 24 meeting on the subject, "Supersonic Aerodynamics." Chairman Reid presided.

California State Polytechnic College

On September 27, two films, *North American Test Instrument Vehicle* and *Aluminum Fabrication Processes*, were shown to the 57 persons who were present. The meeting was led by Vice-Chairman Dave Fuller.

Chairman Herbert Pierce presided over the October 8 meeting at which the film, *Gliding Wings*, was screened. Forty-seven persons were in attendance.

The Catholic University of America

Dr. Max M. Munk, Director, Munk's Aeronautical Laboratory, and Special Lecturer, Catholic University, was the speaker at the October 3 meeting. Dr. Munk, who had spent the summer in England on a project for the Navy Department, gave his impressions of England—its country, people, and governmental research program in the aeronautical sciences. Subsequent to his talk, permanent officers were elected and are as follows: Chairman, Earl Erickson; Secretary, George Veen; and Joint Treasurers, James D. Trent and Joseph Chamberlain. Chairman Erickson closed the meeting, which was attended by 30 persons.

University of Florida

Three films were shown at the October 9 meeting—*Pylon Dusters, Nature Plays Favorites*, and *The Nativ*. Chairman Roy F. Dutton led the meeting with 24 students present.

Indiana Technical College

On October 16, Edward, L. Krout, a student at Indiana Tech, spoke on "Repairs for Wooden Wing Panels." Chairman John W. Whitehurst presided; 23 students were present.

The Johns Hopkins University

The officers for the 1951–1952 academic year are: Chairman, A. G. M. Scoledes; Vice-Chairman, D. S. Johnson; and Secretary, A. L. Kistler; Guy L. Bryan, Professor of Aeronautics, was selected as Faculty Adviser.

University of Maryland

On October 17, A. Wiley Sherwood, Professor of Aeronautical Engineering and Manager of the Wind Tunnel at Maryland, spoke to the 45 assembled students on "The Wind Tunnel, Its History and Use Today." Professor Sherwood is Faculty Adviser of the branch. The meeting was led by Chairman Allen A. Bowers.

Polytechnic Institute of Brooklyn: *The officers and faculty adviser for the 1951–1952 academic year are shown from left to right as follows: William F. Hoffmann, Secretary; Kenneth A. Larsen, Vice-Chairman; Prof. Frederick S. Shaw, Faculty Adviser; Louis F. Strihafka, Chairman; and John D. Sposito, Treasurer.*

Northrop Aeronautical Institute

H. F. Rempt, Chief Staff Electrical Engineer, Lockheed Aircraft Corporation, spoke at the September 27 meeting on the topic, "Influence of Electronics on Aircraft Design." Chairman William E. Martin presided; 24 students were present.

At a dinner meeting on October 2, K. E. Van Every, Chief, Aerodynamics Section, Douglas Aircraft Company, Inc., spoke on "Aerodynamics of High Speed." Chairman Martin presided; 40 persons were in attendance.

The new officers who were installed on October 22 are: Chairman, Fred Welty; Vice-Chairman, R. Zimmerman; Recording Secretary, T. S. Sherrard; Corresponding Secretary, S. M. Zima; and Treasurer, B. A. Nissen.

The University of Oklahoma

A joint meeting was held on October 10 with the local student branches of the American Institute of Electrical Engineers and the American Society of Mechanical Engineers. The speaker was D. Lee Chestnut, Manager of Sales, General Electric Company, whose topic was "Developments in the Power Field." Edwin Jackson, President of the A.I.E.E. student branch presided; 75 students were present.

The Pennsylvania State College

At the October 24 meeting, three films were shown to the 60 attending students. Two of them were entitled *Birth of the B-29* and *Air Progress*. The third film showed some of the fighting in Korea last winter. Chairman George Page presided.

Polytechnic Institute of Brooklyn

On October 2, the following new officers were installed: Chairman, Louis F. Strihafka; Vice-Chairman, Kenneth A. Larsen; Secretary, William F. Hoffman; and Treasurer, John D. Sposito. Professor Frederick S. Shaw, Faculty Adviser, spoke on "Fatigue Failures of Major Aircraft Components."

Two films, *How an Airplane Flies* and *Faster Than Sound*, were shown at the October 23 meeting at which 60 students were present. The first film mentioned was produced by Shell Oil Company, Inc.; the latter one was distributed through the British Information Services. The meeting was presided over by Chairman Louis F. Strihafka.

Rensselaer Polytechnic Institute

On October 10, George J. Mullaney, an Engineer with General Electric Company, spoke on "Large Rocket Testing Problems and Facilities." Jack E. Williams presided; 100 persons attended.

The University of Texas

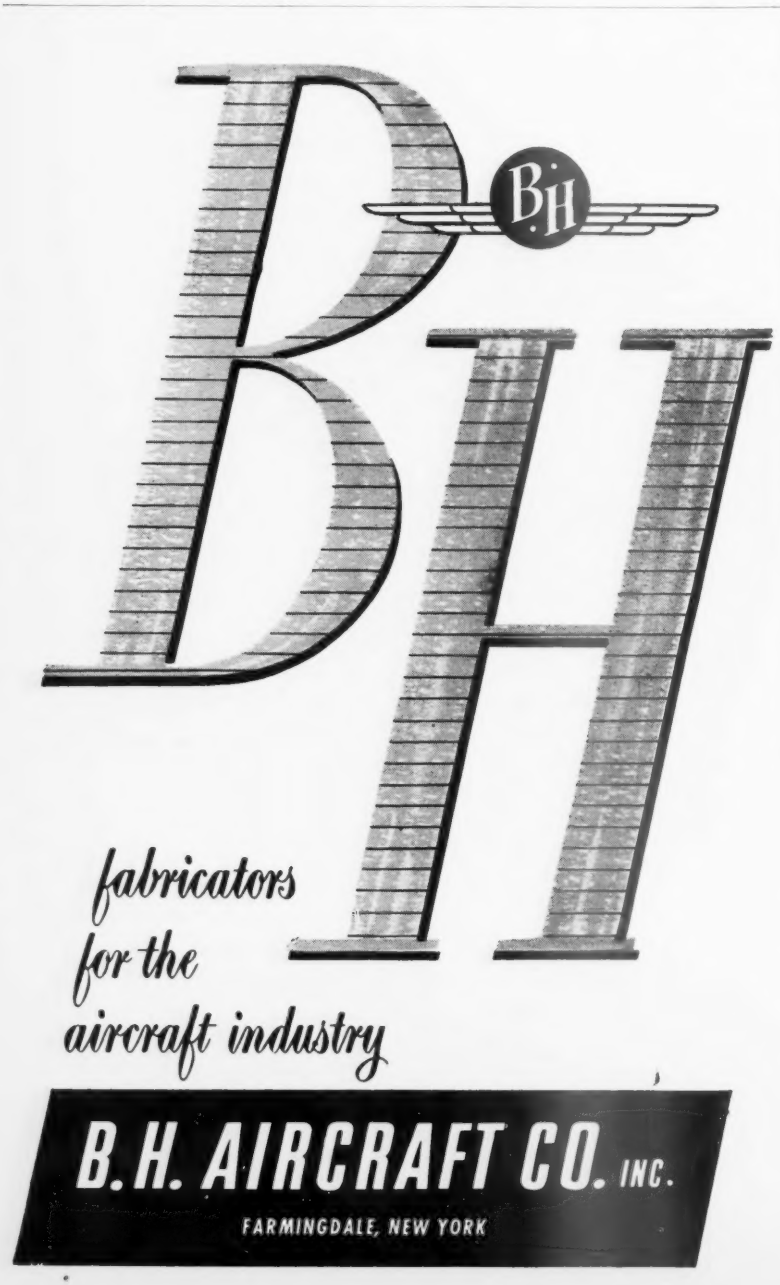
Betty J. Reynolds opened the October 1 meeting at which an election of officers took place with the following results: Chairman, Gerald W. Walker; Vice-Chairman, Charles M. Halsell; Secretary, Shirley Ann Holmgreen; and Treasurer, Betty J. Reynolds. The Faculty Adviser is J. W. Dalley.

Dr. Milton J. Thompson, Chairman Department of Aeronautical Engineering, Texas, spoke to the 20 assembled students on "The History of I.A.S. on National and Local Scale."

United States Naval Academy

At the meeting of October 12, a Naval training film, *One Man Mission*, was shown to the 76 students who were present. Chairman James S. McNeely, Midshipman 1/c, presided.

R. W. Burton, Midshipman 4/c, spoke at the October 19 meeting on "Water Tunnels." Midshipman Burton's talk was accompanied by a film on *Compressibility*. Vice-Chairman Charles H. Kruse, Midshipman 2/c presided; 37 persons were present.



Members Elected

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the REVIEW.

Transferred to Associate Fellow Grade

Benscoter, Stanley U., Ph.D. in Aeronautics, Research Engineer, California Institute of Technology.

Heyl, Edward B., B.S. in M.E., Chief, Statistical Analysis Section, Bureau of Safety Investigation, Civil Aeronautics Board (Washington, D.C.).

Sanders, Newell D., M.S. in M.E., Chief, Physics Div., Lewis Flight Propulsion Lab., N.A.C.A.

Elected to MEMBER Grade

Gatti, Rai, Dott. Ing., Consulting Engineer for Automotive and Aviation Industries, Ufficio Tecnico (Milano, Italy).

Hanchet, W. H. David, B.E., Sales Engineer, Canadian Pratt & Whitney Aircraft Co., Ltd.

Moe, Alfred B., A.B., Airways Engineer, Shore Establishments Div., Bureau of Aeronautics, Dept. of the Navy (Washington, D.C.).

Pearsall, Earle S., Research Physicist, Hughes Aircraft Co.

Price, William G., B.S.Ae.E., Asst. Chief, Landing Gear, Engineering Dept., Bendix Aviation Corp.

Snodgrass, Richard B., M.S.Ae.E., Sr. Aerodynamics Engineer, Consolidated Vultee Aircraft Corp. (San Diego).

Stampley, O. K., Jr., B.S. in Ae.E., Aircraft Design Evaluation Engineer, Civil Aeronautics Administration, 6th Region (Los Angeles).

Transferred to MEMBER Grade

Black, Richard E., M.S. in Ae.E., Stress Analyst "A," Douglas Aircraft Co., Inc. (Santa Monica).

Bonnette, Charles L., B.Sc., Chief Structural Engineer, Globe Corp., Aircraft Div.

Bretoi, Remus N., M.S. in Ae.E., Research Engineer, Aero. Div., Minneapolis-Honeywell Regulator Co.

Brodsky, Robert F., Sc.D., Supervisor of Research, Aeronautics Div., Sandia Corp. (New Mexico).

Bruning, William H., M. of Ae.E., Pilotless Aircraft Design Engineer, Grumman Aircraft Engineering Corp.

Bryan, William C., A.E., Commander, U.S. Navy; Aircraft Engines Officer, Staff ComAirPac. Naval Air Station (San Diego).

Budiansky, Bernard, Ph.D. in Applied Math., Aero. Research Scientist, Structures Theory, Langley Aero. Lab., N.A.C.A.

Carlson, Richard M., M.S. in Ae.E., Structures Engineer, Hiller Helicopters.

Chervenka, Calvin C., B.S. in Ae.E., Graduate Student, University of Texas.

Eckert, Francis M., B.S., Flight Test Instrumentation Engineer, Chance Vought Aircraft Div., United Aircraft Corp.

Glover, Louis S., B.S., Project Engineer, David Taylor Model Basin (Carderock, Md.).

Harkleroad, Edgar L., B.S.Ae.E., Aero. Project Manager, 8- × 10-Ft. Wind Tunnels, Aerodynamics Lab., David Taylor Model Basin, Dept. of the Navy, (Washington, D.C.).

Hildebrand, Robert B., S.M., Aerodynamicist, Boeing Airplane Co. (Seattle).

Judd, Joseph H., M. of Ae.E., Project Engineer, Propulsion Aerodynamics Branch, Pilotless Aircraft Research Div., N.A.C.A., Langley Air Force Base.

Kossar, Arnold F., A.E., Senior Analytical Engineer, Kaman Aircraft Corp.

Leatherbury, Clifton H., Jr., M.S., Project Engineer, Ship Launched Branch, Guided Missiles Div., Bureau of Aeronautics, Department of the Navy (Washington, D.C.).

Lengsholz, Allen J., B.S. in Ae.E., Project Flight Analysis Engineer, Northrop Aircraft, Inc.

Martin, Benjamin P., M.S. in Ae.E., Engineering Designer "B," Preliminary Design, Aerophysics & Atomic Energy Research Lab., North American Aviation, Inc.

Matos, Stephen R., B. of Ae.E., Stress Engineer, Gassner Aircraft Engineering.

Mellen, David L., M.S. in Ae.E., Research Engineer, Aero. Div., Minneapolis-Honeywell Regulator Co.

Nichols, John B., B.Ae.E., Section Head, Aircraft Auxiliary Power Plant Section, General Engineering Lab; Project Engineer on Auxiliary Power Plant System, General Electric Co. (Schenectady).

Nicks, Oran W., B.S. in M.E. (Aero.), Aerodynamicist, North American Aviation, Inc.

Paris, C. James, B.S. in A.E., Structures Engineer, Bendix Products Div., Bendix Aviation Corp.

Rainey, Robert W., M.S. in A.E., Aero. Research Scientist & Aerodynamicist III, N.A.C.A., Langley Air Force Base.

Rowney, James V., A.E., Commander, U.S. Navy; Commanding Officer, Navy Jet Squadron (F 9F-2), VF-112.

Sievers, Alwin G., B.A.E., Senior Test Engineer, Technical Data Div., Wright Aero. Corp., Div. of Curtiss-Wright Corp.

Widmayer, Edward, Jr., M.A.E., Project Engineer, N.A.C.A., Langley Air Force Base.

Elected to Associate Member Grade

Derham, G. L., Section Head (Standards), Design Dept., A. V. Roe Canada Ltd. (Malton).

Haverstick, Ben R., Administrative Division Engineer, Lockheed Aircraft Corp. (Georgia).

Jobe, John B., B.S.—Gen. Engineering, Manager, Aviation Industry Section, Johns-Manville Sales Corp.

Transferred to Associate Member Grade

Goldman, Bernard, M.S., Technical Editor, Stanley Aviation Corp.

Elected to Technical Member Grade

Cenek, Edward J., B.S.Ae.E., Technical Advisor, Reynolds Metals Co. (Chicago Office).

Foody, James J., M.Sc., Aerodynamicist, Short Bros. & Harland, Ltd.

Reynolds, Robert H., B.S., 1st Lt., Radar Controller, 13th A.F., U.S.A.F.

Shive, James C., B.S. in Ae.E., Captain, U.S.A.F.; Electronic Countermeasures Officer, Ramey Air Force Base, (Puerto Rico).

Transferred to Technical Member Grade

Albanese, D. Thomas, B.Ae.E., Test Engineer, Turbo-Prop Stress Group, Design & Development Div., Wright Aero. Corp., Div. of Curtiss-Wright Corp.

Anderson, Lawrence C., Flight Test Analyst "B," Northrop Aircraft, Inc., assigned to Holloman Air Force Base (New Mexico).

Batch, Richard G., B.A.Sc. in Ae.E., Aero. Engineer, Aircraft Design, Stress Dept., DeHavilland Aircraft of Canada.

Baur, Warren C., Instructor, Academy of Aeronautics.

Beebe, Wallace E., B. of Ae.E., Lt. & B-29 Navigator, U.S.A.F.

Bender, Martin D., B.Ae.E., Jr. Stress Engineer, The Glenn L. Martin Co. (Middle River).

Bennett, Walter D., Major, U.S.A.F.; Student Trainee, Assigned to Boeing Airplane Co. (Seattle).

Berks, William I., B. of Ae.E., Research Asst., Polytechnic Institute of Brooklyn.

Bishop, Bruce A., B.S. in Ae.E., Jr. Engineer, Aerodynamics Section, Airframe Group, Bendix Products Div., Bendix Aviation Corp.

Blake, Robert J., Captain, U.S.A.F.; Evaluation Officer, Pilot, Hq. Sq. APG, Eglin Air Force Base.

Brenning, Orin Z., B. of Ae.E., 2nd Lt., U.S.A.F.; Project Officer, Wright-Patterson Air Force Base.

Casagrande, Louis F., B. of Ae.E., Jr. Engineer, Wright Aero. Corp., Div. of Curtiss-Wright Corp.

Christie, Peter St. C., B.A.Sc., Engineering Draftsman, Northrop Aircraft, Inc.

Davis, Dean F., B.S. in Ae.E., Jr. Engineer, Engineering Liaison Dept., Consolidated Vultee Aircraft Corp. (Ft. Worth).

Dearey, Ralph H., Captain, U.S.A.F.; Purchasing & Contracting Officer, 5010th A.B. Group.

Denninger, Thomas C., B. of Ae.E., Asst. Project Engineer, Sperry Gyroscope Co. Div., The Sperry Corp.

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Drinkwater, Ronald C., B.A.Sc., Aircraft Design Engineer, A. V. Roe Canada Ltd. (Malton).

Duff, Thomas A. S., B.A.Sc., Engineering Draftsman, Dorr Co. Engineers.

Eder, Frank W., B.Ae.E., Jr. Aerodynamicist, Republic Aviation Corp.

Filicko, John J., Jr., B. of Ae.E., Jr. Engineer, Piasecki Helicopter Corp.

Freelin, J. Raymond, B. of Ae.E., Jr. Engineer, Structural Analysis & Design, Consolidated Vultee Aircraft Corp. (San Diego).

French, Francis W., Jr., B. of Ae.E., Draftsman, Fuselage Design Group, Grumman Aircraft Engineering Corp.

Goodrich, Robert B., A.A. in Ae.E., Power Plant Design Engineer, Chance Vought Aircraft Div., United Aircraft Corp.

Grape, Richard G., B. of Ae.E., Jr. Engineer, Aerodynamics—Research & Development, Fairchild Guided Missiles Div., Fairchild Engine & Airplane Corp.

Grove, James C., Major & Administrative Officer (Industrial Engineering), U.S.A.F. (Washington, D.C.).

Hansen, George H., B.S. in Ae.E.

Hatfield, Donald J., B.S., Instrumentation Engineer, Guided Missiles, Consolidated Vultee Aircraft Corp. (San Diego).

Herrmann, Raymond C., Engineering Draftsman, North American Aviation, Inc. (Downey).

Hilvosky, Steve E., B.S., Captain & Pilot, U.S.A.F., Patrick Air Force Base.

Horrigan, Clement V., B. of Ae.E., Servo-Automatic Pilot, Airborne Equipment Div., Instrument Branch, Bureau of Aeronautics, Dept. of the Navy (Washington, D.C.).

Hughes, Jack, B.S.A.E., Aero. Engineer, Goodyear Aircraft Corp.

Innes, Robert S., B.A.Sc., Stress Engineer, de Havilland Aircraft of Canada, Ltd.

Irvin, Edward M., B.S.E. in Ae.E., Jr. Engineer, Piasecki Helicopter Corp.

Kaplita, Thaddeus T., B. of Ae.E., Jr. Engineer, Engineering Training Program, Piasecki Helicopter Corp.

Kemp, Donald E., B.S., Flight Test Instrumentation Engineer, Consolidated Vultee Aircraft Corp. (Ft. Worth).

London, Edward P., B. of Ae.E., Detail Draftsman, Weight Saving Group, Republic Aviation Corp.

Lowes, Ernest H., Jr., Instructor in Freshman Engineering Drawing, Texas A. & M. College.

Lull, John L., B. of Ae.E., Jr. Engineer, Airframe Layout & Struct. Design, Cornell Aero. Lab., Inc.

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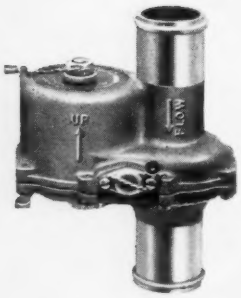

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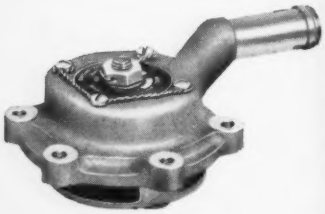

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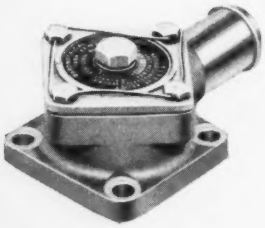

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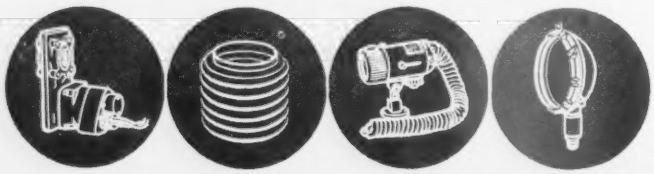

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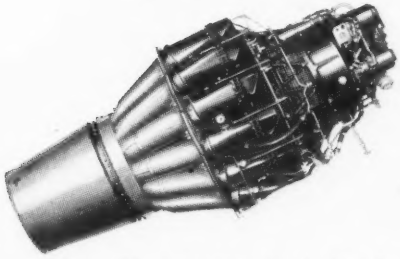

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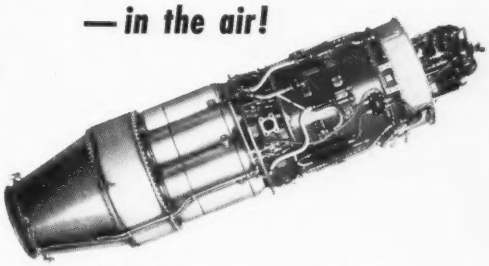

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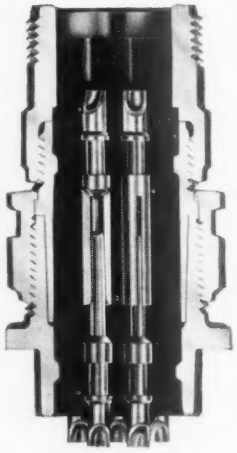

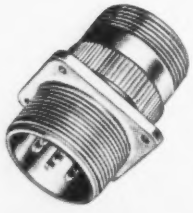

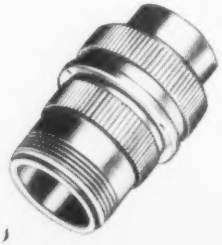

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The abstracts are classified according to the Air Technical Index Distribution Guide. Numbers in parentheses indicate the position of the Division Headings in the numerical arrangement.

Aerodynamics (2) ... 74
Boundary Layer ... 74
Control Surfaces ... 75
Fluid Mechanics & Aerodynamic Theory ... 75
Internal Flow ... 75
Natural Flight ... 78
Parasitic Components & Interference ... 78
Stability & Control ... 78
Wings & Airfoils ... 78
Aeroelasticity ... 78
Air Transportation (41) ... 80
Airplane Design (10) ... 80
Airplane Descriptions ... 80
Landing Gear ... 82
Operation & Performance ... 82
Airports (39) ... 82
Comfortization (23) ... 82
Education & Training (38) ... 82
Electronics (3)
Antennas ... 82
Circuits & Circuit Elements ... 82
Components ... 82
Electronic Tubes ... 83
Measurements & Testing ... 83
Navigation Aids ... 83
Noise & Interference ... 83
Radar ... 83
Saturable Reactors ... 83
Transmission Lines ... 83
Wave Propagation ... 83
Equipment
Electric (16) ... 84
Hydraulic & Pneumatic (20) ... 84
Flight Operating Problems (31)
Ice-Prevention & Removal ... 85
Weather Hazards ... 85
Flight Safety & Rescue (15) ... 85
Flight Testing (13) ... 85
Fuels & Lubricants (12) ... 85
Gliders (35) ... 85
Guided Missiles (1) ... 85
Instruments (9) ... 85
Machine Elements (14) ... 86
Bearings ... 86
Fastenings ... 86
Gears & Cams ... 86
Mechanisms & Linkages ... 86
Shafts & Rotating Discs ... 88
Springs ... 88
Maintenance (25) ... 88
Materials (8) ... 88
Ceramics & Ceramals ... 88
Metals & Alloys ... 88
Nonmetallic Materials ... 88
Protective Coatings ... 90
Sandwich Materials ... 90
Meteorology (30) ... 90
Navigation (29) ... 90
Parachutes ... 90
Photography (26) ... 90
Power Plants
Jet & Turbine (5) ... 91
Ram-Jet & Pulse-Jet ... 91
Reciprocating (6) ... 91
Rocket (4) ... 91
Production (36) ... 91
Propellers (11) ... 92
Reference Works (47)
Bibliographies ... 92
Dictionaries ... 92
Directories ... 92
Yearbooks ... 92
Rotating Wing Aircraft (34) ... 92
Sciences, General (33)
Mathematics ... 93
Mechanics ... 93
Space Travel ... 93
Structures (7) ... 93
Thermodynamics (18) ... 96
Water-Borne Aircraft (21) ... 96
Wind Tunnels & Research Facilities ... 96

II. BOOKS REVIEWED IN THIS ISSUE

Gas Turbines. Harry A. Sorensen ... 99
Reviewed by E. S. Thompson, General Electric Company

Handbook of Supersonic Aerodynamics, Vols. I and II. Johns Hopkins University, Applied Physics Laboratory 99
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Book Notes ... **101**

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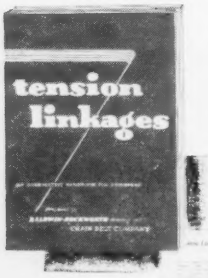

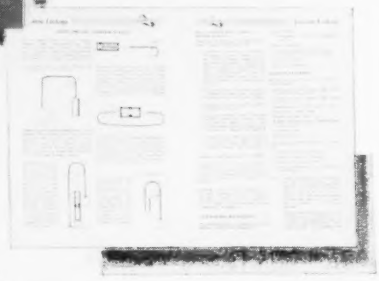

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Aerodynamics (2)

The Derivation and Estimation of Aerodynamic Loads for Stressing Purposes. D. J. Lambert. *Royal Aeronautical Society, Journal*, Vol. 55, No. 489, September, 1951, pp. 561–585, illus. 8 references.

Interpretation and application of the strength requirements of an aircraft to withstand aerodynamic loads; load estimates and stress data in the early stages of aircraft design, and flight test verification of these estimates. Detailed loading calculations are presented for conventional aircraft maneuvers and for the actions of the control surfaces.

Aerodynamic Aspects of the (I.A.S.–R.Ae.S.) Third International Aeronautical Conference. A. H. Flax. *Aeronautical Engineering Review*, Vol. 10, No. 12, December, 1951, pp. 35–39.

BOUNDARY LAYER

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Analysis of the effects of the pressure gradient. The solution of Brainerd and Emmons is extended, neglecting their assumption of constant pressure in the gas stream about the plate. The solution is developed for an insulated flat plate; the analysis leads to an approximation of the effects of heat transfer on the boundary-layer profiles. Measurement of the profiles in a 1- by 2-in. supersonic wind tunnel yielded corrections to the nozzle ordinates for boundary-layer buildup.

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Development of approximate solutions for steady irrotational flows using the Rayleigh-Ritz procedure; formulation of the general problem for the compressible flow past an arbitrary body of revolution.

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$$(\partial u/\partial t) + u(\partial u/\partial x) = \nu(\partial^2 u/\partial x^2)$$

and analysis of its relationship to shock wave and turbulence theory. The solutions illustrate some features of the interaction of nonlinearity and viscosity.

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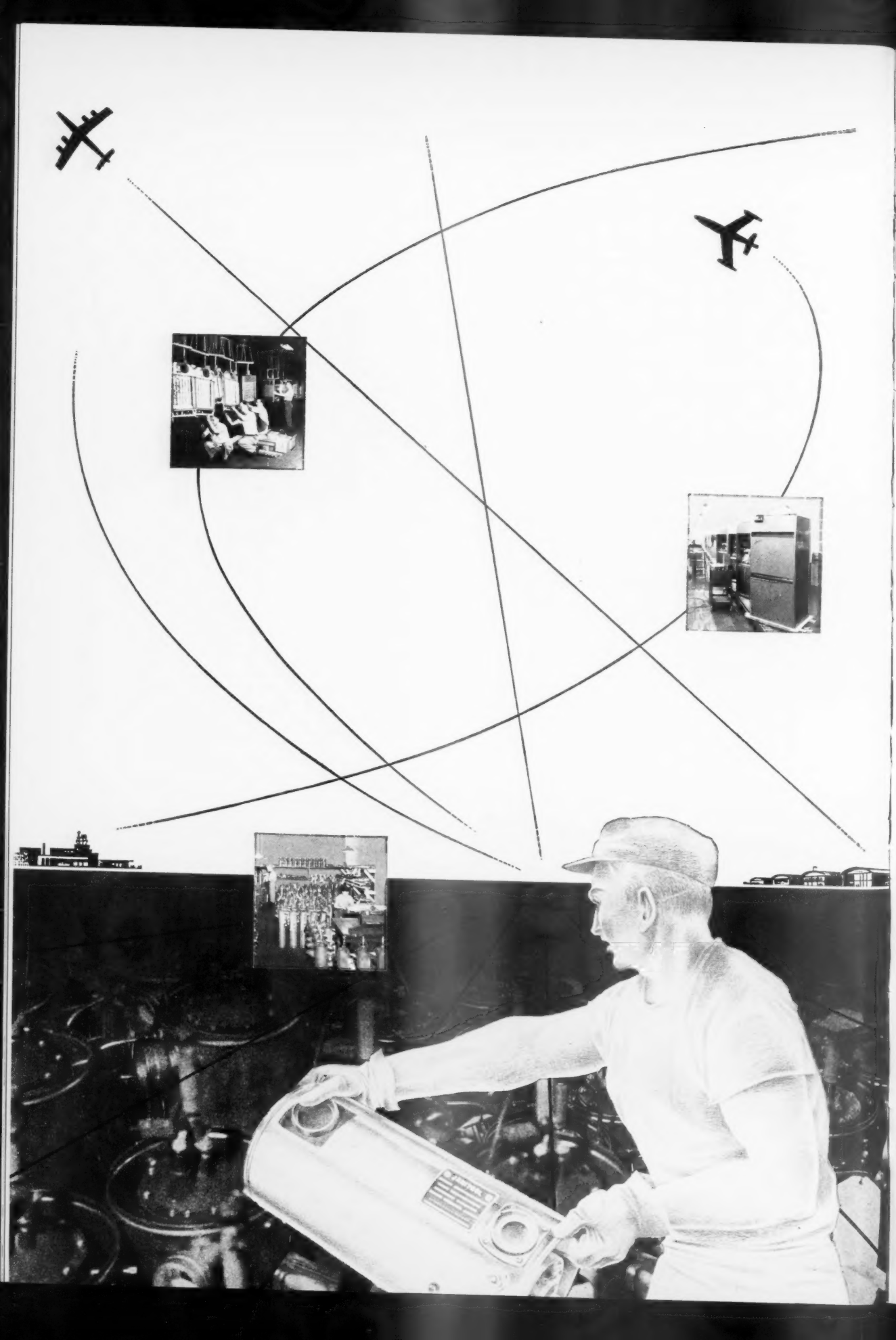
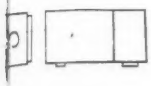
Numerical results and their significance in improved impeller design. Presentation of ten two-dimensional relaxation solutions for compressible and incompressible fluids, for flow with axial symmetry and flow between blades of surfaces of revolution about the axis of the impeller; and three approximate methods of solution for compressible flow between blades on surfaces of revolution.





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Two Axial-Symmetry Solutions for Incompressible Flow Through a Centrifugal Compressor with and Without Inducer Vanes. Gaylord O. Ellis, John D. Stanitz, and Leonard J. Sheldrake. *U.S., N.A.C.A., Technical Note No. 2464*, September, 1951. 34 pp., illus. 13 references.

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Radial-flow turbomachines for gas-turbine uses; analysis of a multistage inflow turbine in which all the rotors are carried on a single rotor disc. The first stage is examined in detail, and the results are adapted to the other stages.

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PARASITIC COMPONENTS & INTERFERENCE

The Forces Acting on an Aerofoil of Approximate Joukowski Type in a Stream Bounded by a Plane Wall. S. Tomotika, Z. Hasimoto, and K. Urano. *Quarterly Journal of Mechanics and Applied Mathematics*, Vol. 4, Part 3, September, 1951, pp. 289–307, illus. 10 references.

Analysis of the effect of the ground on the lift and moment of an airfoil having camber and thickness, applying the method of images. An approximately symmetric Joukowski airfoil is used to estimate the modifications introduced in the ground effect by airfoil thickness.

STABILITY & CONTROL

Effect of an Autopilot Sensitive to Yawing Velocity on the Lateral Stability of a Typical High-Speed Airplane. Ordway B. Gates, Jr., and Leonard Sternfield. *U.S., N.A.C.A., Technical Note No. 2470*, September, 1951. 29 pp., illus. 6 references.

Analysis of the effects of the autopilot on the lateral stability of the aircraft and of the effects on the lateral stability characteristics of inclination of the gyro spin axis to the flight path and of time lag in the autopilot system.

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New Lines of Research into the Stability of Flight. Y. Normand. *Interavia*, Vol. 6, No. 6, June, 1951, pp. 334–336, illus. Analysis of flight stability in which pilot reaction is introduced into the equations that relate aircraft movement and response.

WINGS & AIRFOILS

Application of the Extended Kármán-Tsien Method for the Generation of Conventional Airfoils in Two-Dimensional Subsonic Compressible Flow (Investigations in Aeronautics from the Department of Aeronautical Engineering). Richard M. Mark. *Washington, University, Engineering Experiment Station, Bulletin No. 118 (Aeronautical Series No. 1)*, 1951, pp. 7–11, illus. 4 references.

Generation of conventional airfoils from a circle for compressible flow, using the extended Kármán-Tsien method developed by Lin. The mapping function is determined for a specific case, and it is shown that, if Lin's conditions are satisfied, the procedure is valid for compressible flow.

Two-Dimensional Wind-Tunnel Investigation at High Reynolds Numbers of Two Symmetrical Circular-Arc Airfoil Sections with High-Lift Devices. William J. Underwood and Robert J. Nuber. *U.S., N.A.C.A., Research Memorandum No. L6K22*, March 12, 1947. 35 pp., illus. 2 references.

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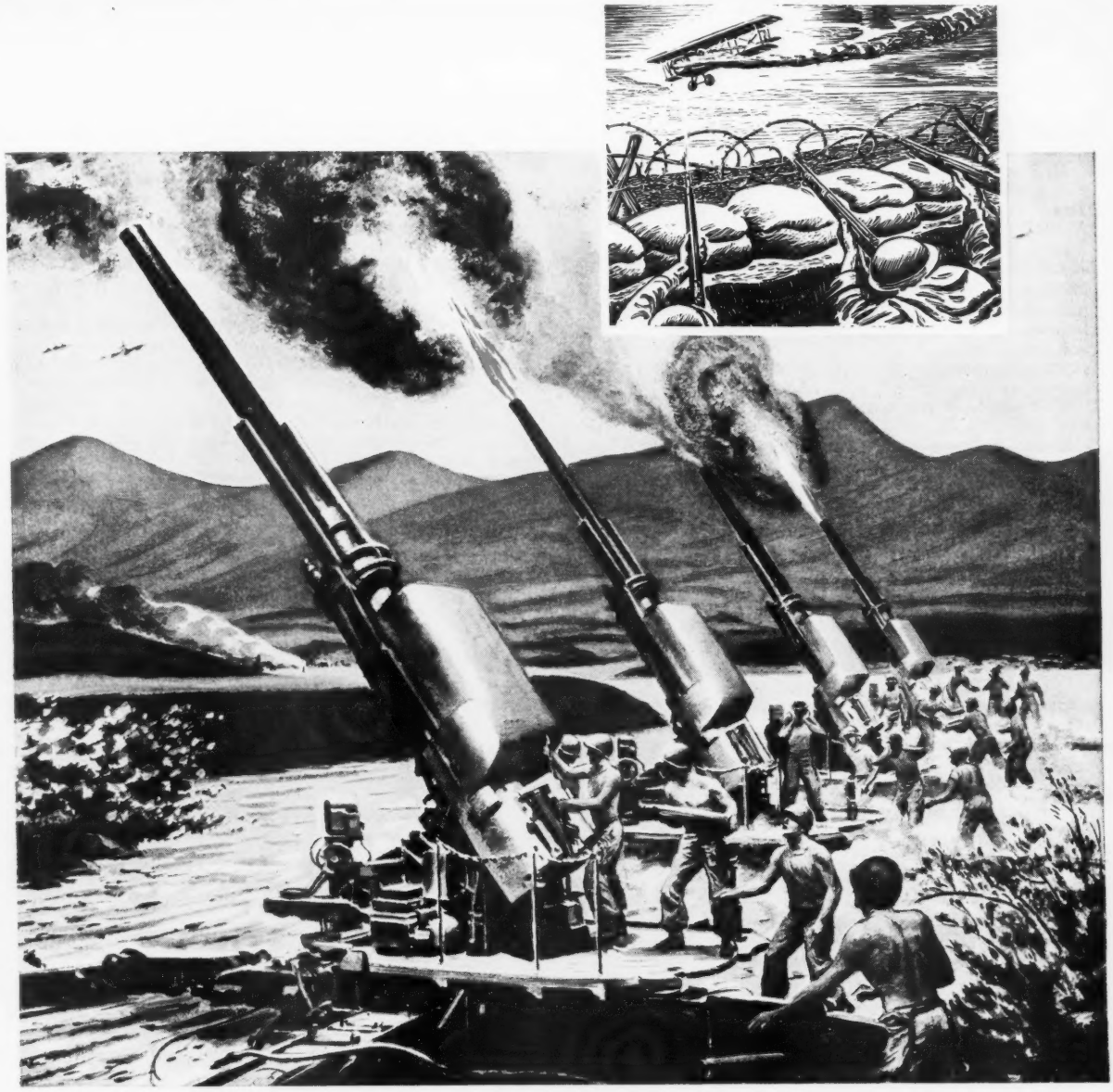
Summary of Information Relating to Gust Loads on Airplanes. Philip Donely. *U.S., N.A.C.A., Report No. 997*, 1950. 51 pp., illus. 44 references. Superintendent of Documents, Washington. $0.40. Review of research on gust, structure, aircraft load responses, and operating statistics of aircraft subject to gust loads, based on studies made prior to October, 1947.

High Speed Aircraft Structure Fatigue. Robert McLarren. *Aero Digest*, Vol. 63, No. 3, September, 1951, pp. 100–108, illus. 15 references. Review of the problem of aircraft structure fatigue; methods of analysis; gust-loading problem; N.A.C.A. V-g Recorder; current research programs.



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Aileron Flutter in a Single Degree of Freedom (Investigations in Aeronautics from the Department of Aeronautical Engineering). K. P. Abichandani and R. M. Rosenberg. *Washington, University, Engineering Experiment Station, Bulletin No. 118 (Aeronautical Series No. 1)*, 1951, pp. 72–76, illus. 9 references. Demonstration of the existence of flutter in the single degree of freedom of elastically restrained aileron rotation; conditions under which this aileron flutter can occur.

Air Forces and Moments on Triangular and Related Wings with Subsonic Leading Edges Oscillating in Supersonic Potential Flow. Charles E. Watkins. *U.S., N.A.C.A., Technical Note No. 2457*, September, 1951. 44 pp., illus. 11 references.

Derivation of formulas for the velocity potential and the forces and moments for a rigid triangular wing performing vertical and pitching sinusoidal oscillations in mixed supersonic flow.

Aerodynamic Coefficients of an Oscillating Airfoil in Two-Dimensional Subsonic Flow. R. Timman, A. I. van de Vooren, and J. H. Greidanus. *Journal of the Aeronautical Sciences*, Vol. 18, No. 12, December, 1951, pp. 797–802, 834, illus. 19 references.

Brief review of the mathematical principles of a complete analytical solution, based on the linearized equations, for the equivalent boundary-value problem in terms of Mathieu and modified Mathieu functions. Lifting and pitching moments in translation and rotation are calculated for $M = 0.35, 0.5, 0.6, 0.7$, and 0.8 and $\omega = 0.1$–3.0.

Study of Vortex Shedding as Related to Self-Excited Torsional Oscillations of an Airfoil. Raymond L. Chuan and Richard J. Magnus. *U.S., N.A.C.A., Technical Note No. 2429*, September, 1951. 49 pp., illus. 3 references. Results of an investigation of the frequency and amplitude of self-excited oscillations of an NACA 0006 airfoil suspended elastically.

On the Deflection of Swept Cantilevered Surfaces. Harold C. Martin and Hemen J. Gursahaney. *Journal of the Aeronautical Sciences*, Vol. 18, No. 12, December, 1951, pp. 805–812, illus. 6 references.

Experimental evidence that leads to the concept of the apparent elastic axis for a swept rectangular plate; effect of the plate root region on the deflection; comparison of experimental and calculated deflections. Experimental data on a swept plate of triangular plan form are compared with calculated values for several sweep angles.

An Instability Problem Arising in Uniform Cantilevered Struts (Investigations in Aeronautics from the Department of Aeronautical Engineering). Harold C. Martin. *Washington, University, Engineering Experiment Station, Bulletin No. 118 (Aeronautical Series No. 1)*, 1951, pp. 95–99, illus. 4 references.

Analysis of the stability of a wind-tunnel model support strut, considering the lift and drag forces transmitted to the strut from the model. These forces cause an instability that is a combination of bending and twisting. A solution is obtained for the first buckling mode of an unswept and untapered strut.

An Observation Regarding the Deflections of Uniform Swept Cantilevered Plates (Investigations in Aeronautics from the Department of Aeronautical Engineering). H. J. Gursahaney and Harold C. Martin. *Washington, University, Engineering Experiment Station, Bulletin No. 118 (Aeronautical Series No. 1)*, 1951, pp. 100–107, illus. 4 references. Experimental evaluation of the application of elementary beam theory to the study of the deflection of swept cantilever plates.

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Solution, based on the use of the Laplace transform, to the problem of a circular plate with free edges, which carries a concentrated mass at its center and which is struck an impulsive blow on the mass. The concentrated mass is replaced by a density impulse; the natural frequencies of vibration are determined as functions of the magnitude of the concentrated mass.

On Elastic Continua with Hereditary Characteristics. Enrico Volterra. *Journal of Applied Mechanics*, Vol. 18, No. 3, September, 1951, pp. 273–279, illus. 12 references.

Extension of the classical equations of motion for elastic media assuming hereditary damping; applications to the free radial vibrations of an isotropic sphere, vibrations of a flexible string, lateral vibrations of bars, and vibrations of membranes.

The Solution of Aeroelastic Problems by Means of Electrical Analogies. R. H. MacNeal, G. D. McCann, and C. H. Wilts. *Journal of the Aeronautical Sciences*, Vol. 18, No. 12, December, 1951, pp. 777–789, illus. 17 references.

Application of the direct component type of analog computer for the solution of aeroelastic problems. Displacements and rotation of points within the air frame are used as coordinates of the aeroelastic system. The air-frame and aerodynamic forces are represented by electric analogies.

Air Transportation (41)

Aspects of Realistic Airplane Economic Analysis. Poul Jørgensen. *Interavia*, Vol. 6, No. 7, July, 1951, pp. 395–397, illus.

Analysis of economic problems of aircraft utilization, based on the fact that economic success depends on how the aircraft matches specific operational and traffic conditions. The influences of seasonal fluctuations, general traffic potential, and the distribution of passenger traffic are included in the study.

Evaluation of the Profitability of Air Service Networks. Carl Pirath. *Interavia*, Vol. 6, No. 9, September, 1951, pp. 515–517.

Investigation of the economics of air transportation in relation to the route network and economic structure of the region served, based on an analysis of the financial reports of U.S. air lines for 1949.

Pillars of World Air Transport. *Interavia*, Vol. 6, No. 9, September, 1951, pp. 490–493. Capital assets and ownership, management, aircraft types and number of aircraft, principal routes, and unduplicated route mileage of the world's scheduled air lines.

Review of Papers on Air Transport (at the I.A.S.—R.Ae.S. Third International Aeronautical Conference). R. W. Rummel. *Aeronautical Engineering Review*, Vol. 10, No. 12, December, 1951, pp. 40, 41.

Airplane Design (10)

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Pounds vs. Dollars in Aircraft Design. M. Francis Taylor and John VanHamersveld. *Aero Digest*, Vol. 63, No. 3, September, 1951, pp. 36, 38, 40, 42, 44, 46, 48, 52, 54, illus. Relationship between design producibility and manufacturing producibility; coordination between the weight and structures department and the cost-control department.

AIRPLANE DESCRIPTIONS

Farnborough, 1951; An Appraisal of Aircraft and Power Plants. *Flight*, Vol. 60, No. 2226, September 21, 1951, pp. 378–383, illus. Military, research, and civil aircraft; helicopters; power plants.

Age of the Triangle. Denis Desoutter. *Aviation Age*, Vol. 16, No. 3, September, 1951, pp. 15–19, illus. General specifications of the Avro 707A and 707B, Boulton-Paul P-111, and Fairey FD-1 British delta-wing aircraft.

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Republic F-84F Single-Engined Turbojet Fighter. *Aero Digest*, Vol. 63, No. 3, September, 1951, pp. 25–32, 34, illus., cutaway drawing.

Saab J29 Single-Engined Turbojet Fighter, Sweden. *Interavia*, Vol. 6, No. 7, July, 1951, pp. 372–375, illus., cutaway drawings.

Introducing— A NEW MEMBER OF THE INCO FAMILY INCOLOY

Incoloy is a wrought nickel-chromium-iron alloy, developed as a nickel-saving companion to Inconel. It is a high temperature material with good resistance to oxidation, strength at elevated temperatures and workability comparable to that of Inconel.

The principal engineering characteristics of Incoloy are:

- **Oxidation Resistance** – the oxidation resistance of Incoloy is of the same order as Inconel. It has a chromium content of 21%.
- **Physical Constants** – Physical constants are similar to type 330 stainless steel.

INCOLOY
Mechanical Property Ranges of Standard Forms at Room Temperature

Form & Condition	Tensile Properties: Tensile Strength 1000 psi.	Yield Strength (0.2% Offset) 1000 psi.	Elongation in 2 in. per cent	Hardness: Brinell 3000 kg.	Hardness: Rockwell
Rod and Bar					
Cold-drawn					
Annealed	75-100	30-55	50-30	120-170	66-86B
As-drawn	100-150	80-125	30-10	180-290	90B-30C
Hot-Rolled					
Annealed	75-100	30-55	50-30	120-170	66-86B
As-rolled	80-120	35-90	50-25	135-220	74-96B
Forged	80-120	35-90	50-25	135-220	74-96B
Wire					
Cold-drawn					
Annealed	75-105	25-55	50-25	.....	.....
Plate					
Hot-rolled					
Annealed	75-105	30-55	50-30	120-180	.....
As-rolled	80-120	35-90	50-25	135-220	.....
Sheet					
Cold-rolled					
Annealed	75-100	30-55	50-30	.....	88B (max.)
Deep drawing and spinning quality	75-100	30-45	55-35	.....	80B (max.)
Strip					
Cold-rolled					
Annealed	75-100	30-50	50-30	.....	84B (max.)
Deep drawing and spinning quality	75-100	30-45	55-35	.....	80B (max.)
Tubing					
Cold-drawn					
Annealed	75-100	30-55	50-30	.....	88B (max.)

- **Expansion co-efficients**—The expansion co-efficients are approximately those for Inconel. Thus Incoloy should have about the same high temperature resistance to cracking under drastic temperature changes. Because of its relatively high nickel content (34%) the structure of Incoloy is stably austenitic showing no tendency to become embrittled by precipitation of sigma or carbidic phases after prolonged exposure to intermediate temperatures.
- **Room temperature properties** – Room temperature mechanical property ranges of Incoloy mill forms are shown in the table on the left:
- **High Temperature Properties** – High temperature strength properties of Incoloy are comparable to those of Inconel.

In terms of behavior in various high temperature environments it is anticipated that Incoloy will be superior to Inconel in resistance to sulfidation, green-rot and molten cyanide salts. Incoloy is comparable to Inconel in resistance to oxidation.

- **Work Hardening**—The rates of work hardening of Incoloy and Inconel are practically identical.
- **Annealing** – Annealing temperatures for Incoloy should be within the range of 1800° F. to 2000° F.
- **Fabrication**—Incoloy is workable, both hot and cold. It is machinable, though high-speed steel tools should be used.
- **Welding** – For metal arc welding, "132" Inconel electrode is recommended for all gauges. For inert gas metal arc, "62" Inconel filler wire is recommended. Sheet or strip up to ¼" may be joined by this method.

Forms supplied—Incoloy is produced in the usual mill forms—billets, rounds, flats, hexagons, sheet and strip, tubing and wire.

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LANDING GEAR

The Determination of Orifice Parameters for Shock Absorbers; An Approximate Method of Evaluating the Area and Predicting Landing-Gear Performance from Step-by-Step Calculations. J. Nightingale. *Aircraft Engineering*, Vol. 23, No. 271, September, 1951, pp. 261, 262, illus.

OPERATION & PERFORMANCE

Armstrong Whitworth Apollo Four-Engined Turbojet Transport, England. H. R. Watson. *Mechanical Engineering*, Vol. 73, No. 10, October, 1951, pp. 795–798, illus. (Based on a paper: Propeller-Turbine Aircraft, with Special Reference to the Apollo.)

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The Load Transmission Test for Flexible Paving and Base Courses. II—Triaxial Test Data on Structural Properties of Granular Base Materials. William M. Aldous, Raymond C. Herner, and M. H. Price. *U.S., C.A.A., Technical Development Report No. 144*, June, 1951. 34 pp., illus. 2 references.

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Aircraft Heater Test Set-Up. II. Tony Finiels. *Aircraft Heating Digest*, Vol. 11, No. 3, August, 1951, p. 3, illus. Heater test and overhaul procedures used by Eastern Airlines.

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Evaluation of the School Link As an Aid in Teaching Ground Reference Maneuvers (Human Engineering Systems Studies). Edward L. Brown, William G. Matheny, and Ralph E. Flexman. (University of Illinois.) *U.S., Office of Naval Research, Special Devices Center, Technical Report No. SDC 71-16-7*, December, 1950. 41 pp., illus. 1 reference.

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Numerical design calculations for a typical linear super-gain array to demonstrate the speed with which the design becomes impractical as the directivity is increased.

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Use of temperature controllers as amplifiers for transducers; construction details of temperature controllers; types of circuits; design of a mechanical detector that employs a galvanometer as a null detector.

Wide-Range Variable-Frequency Oscillator. A. Cormack. *Wireless Engineer*, Vol. 28, No. 336, September, 1951, pp. 266–270, illus.

Phase-shift oscillator that can operate up to 180 megacycles per sec. The oscillator consists of a phase-shift network composed of four cathode followers connected in cascade and a single-stage RC-coupled amplifier connected in a ring. Bandwidths greater than one octave can be obtained. A frequency-control circuit is used to vary the amplifier load.

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Wobbled audio output or variable single tone is obtained over a 20-to-1 frequency range, using Thyrite or Varistor elements in a modified Wien-bridge circuit. A thermistor stabilizes bridge amplitude.

A Fiftyfold Momentary Beam Intensification for a High-Voltage Cold-Cathode Oscillograph. John H. Park. *U.S., National Bureau of Standards, Journal of Research*, Vol. 47, No. 2, August, 1951, pp. 87–93, illus. 5 references. (Also available as *Research Paper No. 2231*. Superintendent of Documents, Washington. $0.10.)

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R-F Standards Capacitors for Minute Increments. John A. Conner. *Electronics*, Vol. 24, No. 10, 1951, pp. 250, 252, 254, 256, 258, 260, 262, illus.

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The JETEC (Joint Electron-Tube Engineering Council) Approach to the Tube-Reliability Problem. Jerome R. Steen. *Institute of Radio Engineers, Proceedings*, Vol. 39, No. 9, September, 1951, pp. 998–1000, illus.

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Construction, gain considerations, and gain-loss curves of a traveling-wave tube that is a wide-band low-noise low-level exponential amplifier for frequencies between 100 and 1,000 megacycles.

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Induced Grid Noise and Noise Factor. R. L. Bell. *Institute of Radio Engineers, Proceedings*, Vol. 39, No. 9, September, 1951, pp. 1059–1063, illus. 8 references.

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An Octave-Band Analyzer for Noise Measurements. A. P. G. Peterson. *General Radio Experimenter*, Vol. 26, No. 4, September, 1951, pp. 1–7, illus. 8 references.

Design, characteristics, and examples of the use of the portable General Radio Type 1550-A Octave-Band Noise Analyzer, which consists of a filter set, amplifier, indicating meter, and portable battery supply. The frequency range from 20 to 10,000 cycles per sec. is divided into eight bands for analysis; the six middle bands are each an octave in width; the others are a low-pass and a high-pass filter.

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The Design of Transmission-Line Tuning Elements for Minimum Dissipation. R. W. Klopfenstein. *Institute of Radio Engineers, Proceedings*, Vol. 39, No. 9, September, 1951, pp. 1089–1094, illus. 12 references.

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Field Representations in Spherically Stratified Regions. Nathan Marcuvitz. *Communications on Pure and Applied Mathematics*, Vol. 4, No. 2/3, August, 1951, pp. 263–315. 8 references.

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The Correlation Function in the Analysis of Directive Wave Propagation. Henrik Nodtvedt. *Philosophical Magazine*, Vol. 42 (7th Series), No. 332, September, 1951, pp. 1022–1031, illus. 7 references. Application of the auto-correlation function to the directive properties of waves that cover a wide frequency spectrum.

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HYDRAULIC & PNEUMATIC (20)

Dynamic Response of Hydraulic Systems. Harold Raiklen. *Machine Design*, Vol. 23, No. 9, September, 1951, pp. 137–140, illus. Stability and performance, system physical constants, and block diagram of an aircraft control system; time lag and error.

An Emergency System for Hydraulically-Operated Flight Controls. Karl H. Pech. *Hydraulic Engineer*, Vol. 1, No. 3, August-September, 1951, pp. 4, 5, illus. Circuit and the sequence of operations for the changeover from hydraulic to manual operation of the hydraulic control system in the Chance-Vought Cutlass.

Hydraulic Power Control in Sikorsky Helicopters. Walter Gerstenberger. *Hydraulic Engineer*, Vol. 1, No. 3, August-September, 1951, pp. 3, 7, illus.

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A New Approach to the Design of Metering Pins in Oleo Struts (Investigations in Aeronautics from the Department of Aeronautical Engineering). H. P. Durand and R. M. Rosenberg. *Washington, University, Engineering Experiment Station, Bulletin No. 118 (Aeronautical Series No. 1)*, 1951, pp. 61–71, illus.

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Nose-Wheel Steering Systems. H. G. Conway. *Royal Aeronautical Society, Journal*, Vol. 55, No. 489, September, 1951, pp. 586–591, illus. Requirements of nose-wheel steering hydraulic systems.

Design Recommendations for O-Ring Seals. J. H. Swartz. *Product Engineering*, Vol. 22, No. 9, September, 1951, pp. 162, 163, illus. Drawings show correct design practices.

Discussion on "Energy Losses in Hydraulic System," by Nils M. Sverdrup. Victor Tatarinov. **Author's Reply.** *Product Engineering*, Vol. 22, No. 9, September, 1951, pp. 270, 272–274, 276.

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Pneumatic Actuators for Remote Control Systems. D. P. Eckman and R. B. Werey. *Product Engineering*, Vol. 22, No. 9, September, 1951, pp. 151–155, illus.

Proper selection of pneumatic actuators, based on an analysis of the forces and loads involved. Diagrams and analyses explain the operation and construction of spring-diaphragm and spring-piston motors, springless motors, and rotary motors.

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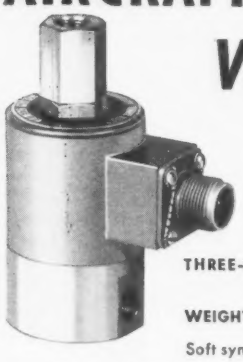

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Flight Operating Problems (31)

ICE-PREVENTION & REMOVAL

The Icing Problem. S. S. Schaetzel. *Flight*, Vol. 60, No. 2223, August 31, 1951, pp. 246–248, illus. 8 references.

Meteorological factors that affect the rate and amount of ice formation; calculation of the maximum icing that can occur; mechanical, chemical, and thermal (electric and hot-gas) protection systems.

Comparison of Heat Transfer from Airfoil in Natural and Simulated Icing Conditions. Thomas F. Gelder and James P. Lewis. *U.S., N.A.C.A., Technical Note No. 2480*, September, 1951. 51 pp., illus. 7 references.

Study of heat transfer from an N.A.C.A. 65,2-016 airfoil in clear air and in icing over a range of controlled conditions in the N.A.C.A. Lewis 6- by 9-ft. icing-research tunnel; validity of tunnel data.

An Empirical Method Permitting Rapid Determination of the Area, Rate, and Distribution of Water-Drop Impingement on an Airfoil of Arbitrary Section at Subsonic Speeds. Norman R. Bergrun. *U.S., N.A.C.A., Technical Note No. 2476*, September, 1951. 151 pp., illus. 9 references.

Derivation of a method that is a generalization of the results of water-drop-trajectory computations on five airfoils of 15 per cent thickness over a moderate C_L range. The procedure for using the method is explained.

Weight Comparison of De-Icing System. C. K. McBaine. *Aero Digest*, Vol. 63, No. 3, September, 1951, pp. 72, 74, illus. Weight comparison of a conventional electrically-heated and a jet-engine air-bleed deicing system.

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Flight Safety & Rescue (15)

NACA Review of Fire Extinguishment Related to Aircraft Fires. Lewis A. Rodert. *National Fire Protection Association, Committee on Aviation and Airport Fire Protection, Bulletin No. 69*, June, 1951. 5 pp. 5 references. Principles of extinguishing crash and flight fires; present extinguishing methods and agents; future trends.

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Design of a balancing machine that uses only standard mechanical parts. The artificial unbalances are excited by four eccentrically supported rotating discs; gear trains that have one or more identical epicyclics as the controlling elements form the mechanical couplings. The vibration indicator yields only qualitative values.

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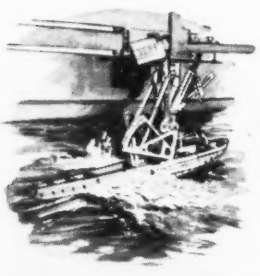

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SHAFTS & ROTATING DISCS

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Douglas Service, Vol. 9, No. 4, July-August, 1951. 20 pp., illus. DC-3, -4, -6, C-54.

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A High Temperature Porcelain Enamel for Tungsten. John C. Horsfall. (*Ceramic Society, Bulletin*, Vol. 29 No. 9, September, 1951, pp. 314, 315.) *Washington, University, Engineering Experiment Station, Reprint No. 43*, 1951. 2 pp., illus. 1 reference. Apparatus and method for applying and firing an impermeable porcelain enamel coating on tungsten.

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Characteristics and results of tests on VPI 260, a volatile synthetic organic chemical powder that produces corrosion-inhibiting vapors. The active ingredient of VPI is dicyclohexylammonium nitrite. Developed by Shell Oil Co., VPI does not coat the surface of the part; it renders the oxygen-water in the atmosphere noncorrosive.

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Sierracin Used in Edge-Lighted Panels. *Aviation Week*, Vol. 55, No. 11, September 10, 1951, pp. 51, 52.

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Derivation of formulas for long and short columns with deflection stresses. The eccentricity is simply represented and any condition of side loading can be expressed in terms of the bending stresses induced by it. Application of the formulas is illustrated.

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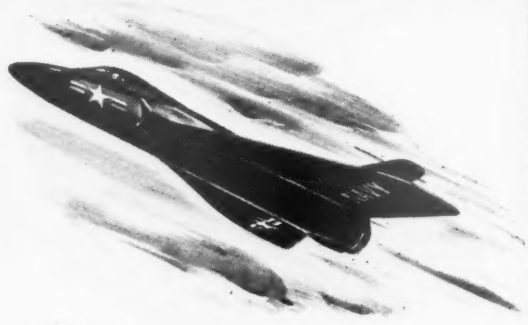

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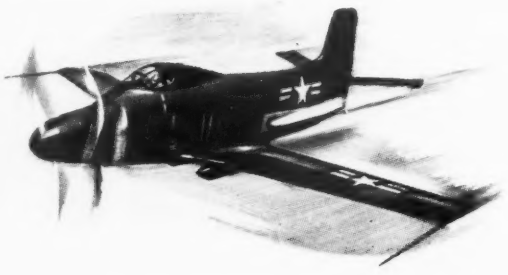

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Development of a graphical method of solution for obtaining, as a function of time, the quantity of heat crossing the inner surface of a hollow cylinder whose surface temperature is suddenly changed; comparison with analytical solutions and experimental results.

Behavior of Fast Moving Flow of Compressible Gas in Cylindrical Pipe in Presence of Cooling. G. A. Varshavskii. (*Zhurnal Tekhnicheskoi Fiziki, U.S.S.R.*, Vol. 16, No. 4, 1946, pp. 413–416.) *U.S., N.A.C.A., Technical Memorandum No. 1274*, September, 1951. 8 pp., illus. 4 references.

Analysis of Errors in Measuring Thermal Conductivity of Insulating Materials. Edward V. Somers and Joseph A. Cyphers. *Review of Scientific Instruments*, Vol. 22, No. 8, August, 1951, pp. 583–586, illus. 2 references.

Analysis of the maximum errors due to the loss of heat by convection in thermal conductivity measurements by the guarded-hot-plate method. Charts give the maximum errors for square and round specimens.

Experimental Investigation of Forced-Convection Heat-Transfer Characteristics of Lead-Bismuth Eutectic. Bernard Lubarsky. *U.S., N.A.C.A., Research Memorandum No. E51G02*, September 20, 1951. 30 pp., illus. 4 references. Data on Pb-Bi flowing in a circular tube with heat addition and on Pb-Bi flowing in an annulus with heat extraction from the inner surface.

Approximate Calculation of Specific Heats for Polyatomic Gases. R. V. Meghreblian. *American Rocket Society, Journal*, Vol. 21, No. 5, September, 1951, pp. 127, 128, 131. 20 references.

Water-Borne Aircraft (21)

An Experimental Study of Water-Pressure Distributions During Landings and Planing of a Heavily Loaded Rectangular Flat-Plate Model. Robert F. Smiley. *U.S., N.A.C.A., Technical Note No. 2453*, September, 1951. 39 pp., illus. 18 references.

Pressure distribution, velocity, draft, wetted length, and acceleration data obtained from smooth-water impact and planing tests. The data are analyzed to determine the effects of instantaneous flight-path angle, beam loading, and velocity of the peak-pressure point on the pressure distribution.

Hydrodynamic Notes on the (I.A.S.–R.Ae.S.) Third International Aeronautical Conference. Ernest G. Stout. *Aeronautical Engineering Review*, Vol. 10, No. 12, December, 1951, pp. 49, 50, illus.

Flying Boat Designs Meet Highspeed Goal. *Aviation Week*, Vol. 55, No. 14, October 1, 1951, pp. 20–22, 24–26, illus. (Based on a paper: A Review of High-Speed Hydrodynamic Development, by Ernest G. Stout.)

The Flying Boat, with Special Reference to the (Saunders-Roe) Princess. Henry Knowler. *Mechanical Engineering*, Vol. 73, No. 10, October, 1951, pp. 799–802, illus. Operation for long-stage routes; relationship of size, pay load, and optimum economic operation.

Wind Tunnels & Research Facilities

Sweden's Unique Jet Engine Laboratory. *Interavia*, Vol. 6, No. 7, July, 1951, pp. 387, 388, illus. General design, instrumentation, and test rigs for testing full-size components of jet engines under realistic airflow and air-pressure conditions.

Criterions for Condensation-Free Flow in Supersonic Tunnels. Warren C. Burgess, Jr., and Ferris L. Seashore. *U.S., N.A.C.A., Research Memorandum No. E9E02*, June 16, 1947. 41 pp., illus. 10 references.

Jet-Boundary Corrections for Complete and Semispan Swept Wings in Closed Circular Wind Tunnels. James C. Sivells and Rachel M. Salmi. *U.S., N.A.C.A., Technical Note No. 2454*, September, 1951. 64 pp., illus. 13 references.

Tables and curves of the induced-upwash-velocity factors, due to the jet boundary, for closed circular and bipolar wind tunnels; computation procedures for the corrections to lift, drag, pitching-moment, yawing-moment, and rolling-moment coefficients.

The Flat Plate Laminar Boundary Layer in a Steady Accelerated Compressible Fluid (Investigations in Aeronautics from the Department of Aeronautical Engineering). Howard A. Stine. *Washington, University, Engineering Experiment Station, Bulletin No. 118 (Aeronautical Series No. 1)*, 1951, pp. 12–25, illus. 8 references.

Analysis of the effects of the pressure gradient. The solution is developed for an insulated flat plate; the analysis leads to an approximation of the effects of heat transfer on the boundary-layer profiles. Measurements of the boundary-layer profiles in a 1- by 2-in. supersonic wind tunnel yielded corrections to the supersonic nozzle ordinates for boundary-layer buildup.

Readers' Forum: A Note on Wind-Tunnel Wall Effect Corrections for Rectangular Airfoils. K. G. Merriam. *Journal of the Aeronautical Sciences*, Vol. 18, No. 12, December, 1951, p. 845.

The Passage of Turbulence Through Wire Gauzes. A. A. Townsend. *Quarterly Journal of Mechanics and Applied Mathematics*, Vol. 4, Part 3, September, 1951, pp. 308–320, illus. 9 references.

Measurement of the turbulent intensities after the passage of isotropic turbulence through fine-mesh wire gauzes; analysis of the data in accordance with the Taylor-Batchelor theory of gauzes and with the properties of isotropic turbulence.

(*Continued on page 109*)

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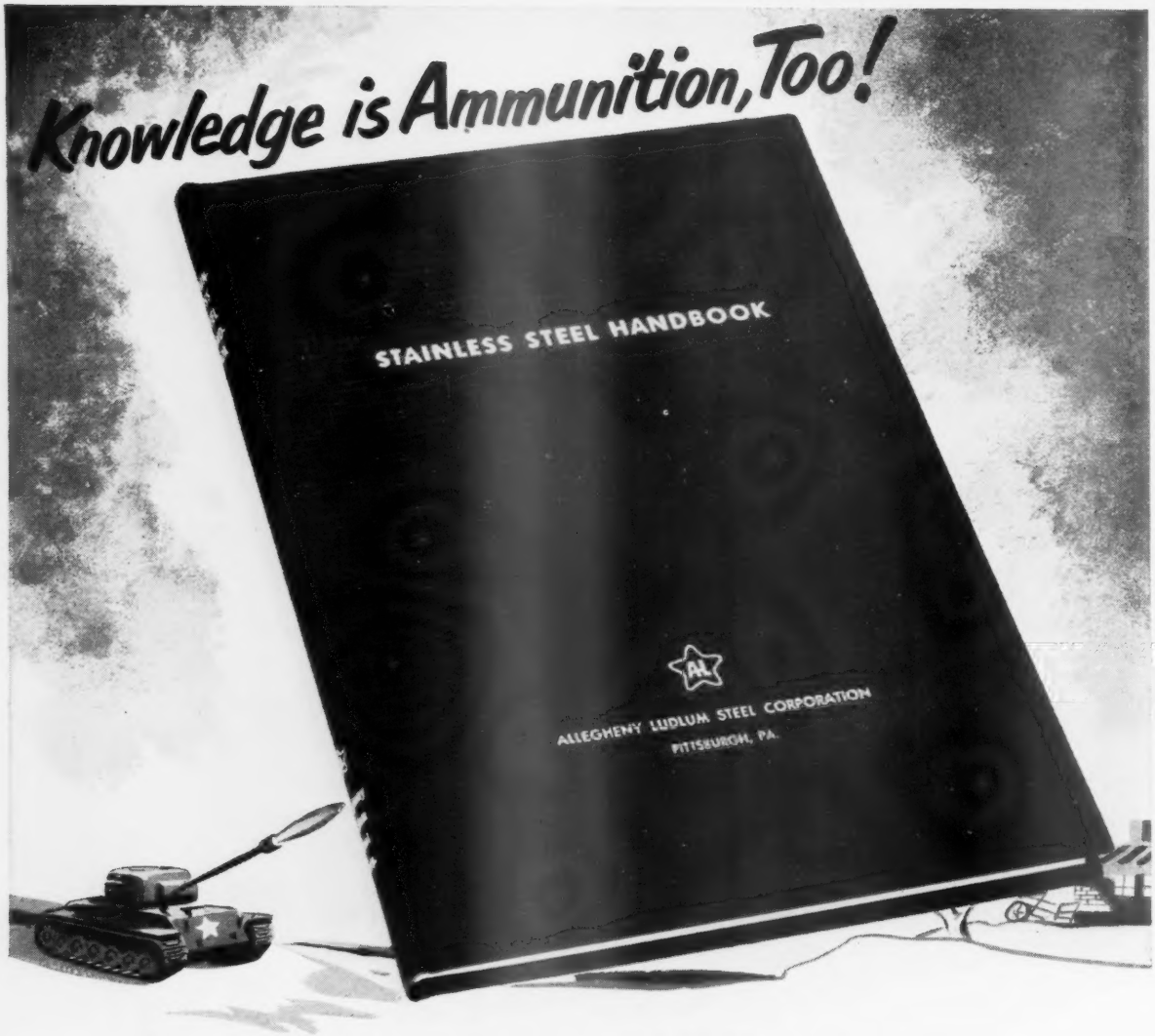

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Aeronautical Reviews — BOOKS

Gas Turbines

By Harry A. Sorensen. New York, The Ronald Press Company, 1951. 460 pp., illus., figures. $6.50.

In his textbook, *Gas Turbines*, Harry A. Sorensen has succeeded in thoroughly covering the gas-turbine field in an interesting, concise manner. The result is an excellent textbook for students and an ideal reference book for people in the gas-turbine and allied fields.

A Professor of Mechanical Engineering at the Institute of Technology, State College of Washington, Sorensen has minimized theoretical aerodynamics and gas flow in favor of giving the student descriptive material emphasizing construction and arrangement of gas-turbine power plants. To this end, he has presented a thorough and fundamental discussion of the thermodynamic principles, the elements of design, and the general construction features of the gas turbine.

Rather than differentiate between the dynamic or aircraft units and static power plants for stationary, marine, and rail installations, Professor Sorensen, in his text, treats the gas-turbine field as a whole. However, the distinguishing characteristics of aircraft gas turbines together with other major types or applications of the gas-turbine power plants have been emphasized through the use of pictures and operating data under pertinent subject divisions.

Throughout the book, Sorensen keeps in mind the fact that this is a text for students. Although students using this book are expected to have completed a course in the elements of engineering thermodynamics, a chapter on this subject has been incorporated for review purposes. Although he does not attempt to discuss control systems or detailed mechanical design, sufficient theory of design is included to familiarize the student with the general principles that are employed in the gas-turbine field.

Sorensen adequately covers the thermodynamic aspects of powerplant design and the aerodynamic design of major engine components such as the compressor, combustion system, turbine, and jet nozzle through diagrams, examples, and problems for student solution. Whenever he has the opportunity, the author also makes use of material published by experts on each phase of turbine design. Many valuable graphs, representing extensive research, testing, and calculation, are included in this material.

In addition to the basic gas-turbine cycles, variations of these are treated with full discussion and calculations of the effects of regeneration, intercooling, reheating, and other such cycle refinements. Thermodynamic relationships are rigorously derived and explained thoroughly as to application.

Because of its extensive coverage of this phase of turbine work and because of its presentation of the basic lines of development, such as axial versus centrifugal compressors, the book could well be used for reference in the gas-turbine and allied fields.

A list of chapter headings in Sorensen's text includes: (1) Introduction; (2) Principles of Thermodynamics; (3) Simple Open-Cycle Gas Turbines; (4) Variations of the Basic Cycle; (5) Closed-Cycle Gas Turbine Plants; (6) The Axial-Flow Compressor; (7) Centrifugal and Positive Displacement Compressors; (8) Axial-Flow Turbines; (9) Combustion Systems; (10) Structural Design; (11) Plant Performance; and (12) Miscellaneous Plants.

The Appendix also includes a table of Properties of Air and Combustion Gases and problems to be solved by the student.

Professor Sorensen has been highly successful in accomplishing his objective—a concise and informative textbook written with an understanding of the student's needs while exploring the field of "Gas Turbines."

E. S. Thompson
Manager—Contracts Operation
Aircraft Gas Turbine Department
General Electric Company

For information on I.A.S. Library Service Facilities, see page 73

Statements and opinions expressed in Book Reviews are to be understood as individual expressions and not necessarily those of the Institute.

Handbook of Supersonic Aerodynamics

Volumes I and II. Johns Hopkins University, Applied Physics Laboratory. (U.S., Bureau of Ordnance, Navord Report No. 1488.) Washington, U.S. Govt. Printing Office, 1950. Misc. paging.

The publication of *Handbook of Supersonic Aerodynamics* will certainly be welcome news to the designers and students of supersonic aircraft. According to the tentative table of contents, the whole handbook will contain the following 21 sections:

Symbols and Nomenclature; Fundamental Equations and Formulae; General Atmospheric Data; The Mechanics and Thermodynamics of Steady One-Dimensional Gas Flow; Collected Tables (Mach Tables, Adiabatic Tables, Miscellaneous Functions of γ); Viscosity Effects; Compressible Flow and Shock Patterns; Two-Dimensional Airfoils; Three-Dimensional Wings; Three-Dimensional Bodies; Mutual Interference Phenomena; Static Stability; Dynamic Stability; Aero-Elastic Phenomena (Flutter); Tables of Thermal Properties of Gases; Ducts, Nozzles and Diffusers; Heat Transfer; Free Jets; Wind Tunnel Design and Instrumentation; Measurement Techniques; Miscellaneous Problems.

The present Volume I contains the first four sections, and Volume II contains the fifth section.

Section 1, Symbols and Nomenclature, represents a verbatim reproduction of the American Standard Letter Symbols for Aeronautical Sciences which was published by the American Standards Association.

Section 2 gives a summary and brief derivations of the fundamental equations and formulas. These include the following topics: equation of continuity, Navier-Stoke's equations, thermodynamic definitions and relations, Bernoulli's formulas, pressure-velocity relations from Bernoulli's formula and the adiabatic formula, the Mach Number, the circulation of a fluid, basic partial differential equations for isentropic steady flow, formulas for isentropic channel flow, flow relations near the speed of sound, Laval nozzle equations, Prandtl-

Meyer flow, and plane shock wave relations for two-dimensional steady flow.

A collection of atmospheric data—such as temperature, density, pressure, composition—is included in Section 3. These data are given in three ranges of altitude: the lower atmosphere from 0 to 65,000 ft.; the upper atmosphere from 65,000 to 393,700 ft.; and the atmosphere extending to extreme altitudes of 300 miles.

Section 4 presents a one-dimensional analysis for flow with or without shocks. For flow without shocks, the analysis takes into account the simultaneous effects of area change, wall friction, drag of internal bodies, external heat exchange, chemical reaction, change of phase, injection of gases, and changes in molecular weight and specific heat. Examples are given for various types of flow. For flow through a discontinuity, the analysis allows for energy, shock, drag, gas injection effects, and changes in gas properties. This analysis is applicable to such processes as the adiabatic normal shock, combustion, moisture-condensation shocks, and steady explosion waves.

Volume II of the handbook contains Section 5, which covers the following topics: (a) isentropic flow functions, (b) normal shock flow functions, (c) oblique shock flow functions, (d) Prandtl-Meyer flow functions, (e) Busemann coefficients, and (f) altitude functions.

Each subsection contains a brief discussion, a list of symbols, equation and descriptive graphs, as well as tabulated values for the functions.

DR. C. T. WANG
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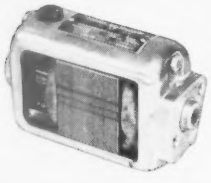

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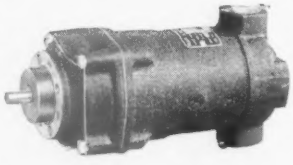

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Through a Better Understanding of the Machining Process, and Control of Materials, Tools, Machines. Vol. 2, Machinability Research Program, Sponsored by U.S. Air Force. Wood-Ridge, N.J., Curtiss-Wright Corporation, 1951. 196 pp., illus., diagrs., folding chart.

This 1951 Air Force machinability report is an important interim document in the changing production picture. Its purpose is to pass on the results of current applied research in this field. Incidentally, its producers have exerted themselves to an unusual degree to accomplish this object without pain to the reader.

The keynote of Volume 1 was "work piece microstructure determines tool life and optimum cutting conditions." This is further substantiated in the present report. A complete and easily read series of charts makes it possible for the process and production man to immediately apply the results to his problems.

The knowledge that a given type of hardenable steel cuts more easily in the annealed state is not exactly news. Nor is it startling to find that hardness is a rough general index of machinability. The book, however, presents in a limited compass the exact relations among cutting speed, heat-treatment (microstructure), cut-metal volume, and tool life for twelve steels common to aircraft production. This wide actual selection plus the use of the principle mentioned allow a justifiable extrapolation to almost any steel one might encounter.

The procedure used in compiling the data is fully described so that due allowance may readily be made when different conditions are encountered. A few specific applications to production problems are treated in detail.

The sections devoted to each of the twelve steels describe their particular peculiarities. Following these, a few pages are used to set forth the principal support for the keynote, "workpiece microstructure determines tool life." The illustrations on pages 138 and 139 are excellent evidence for the case. Another short section presents a synopsis of machine tool trouble shooting, a subject treated at greater length in the first volume. Three brief units close the book.

The first, The Effect of Machining on the Endurance Limit, reports on extensive studies undertaken at the Wright plant, some of them on full-

size propeller blades. The reports are useful, though fragmentary, and their worth probably lies in discussion of methods, variables, etc.

Machining Titanium Alloys comes next and will be for many the most interesting part of the book. It is pointed out that, in general, titanium and its alloys machine very much like the jet engine alloys. Tool life versus cutting speed and cutting speed versus cutting time are charted. Titanium's property of rapid work hardening and its production of tough stringy chips are noted.

Turning, milling, cutting off, drilling, and tapping of titanium are briefly treated, and suggestions to alleviate the well-known difficulties are made. For example, in milling, one company reports the high-speed steel or cast-alloy type cutter to be superior to the carbides. Eccentric drilling with notched drills is recommended for hole making.

An appendix on the Control of Microstructure does a commendable job in presenting the modern concepts of heat-treatment in a simple way. Pages 192 and 193 illustrate, for example, the processes of hardening, annealing, tempering, austempering, martempering, and isothermal annealing by reference to the S curve.

JAMES L. G. FITZPATRICK
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Book Notes

AIRPLANE DESIGN

Russia's Jets and Other Aircraft. William Green and Derek Wood. Sevenoaks, Kent, England, Smith & Hallam Ltd., 1951. 59 pp., illus., diagrs. 3s.

Thirty-four current Soviet aircraft—fighters, bombers, transports, gliders, trainers, liaison airplanes, and helicopters—are described and illustrated in this pocket-size book. A brief development history, a résumé of design features and specifications, a three-view line drawing, and a photograph or artist's sketch are given for 26 of the aircraft.

ELECTRONICS

High Frequency Transmission Lines. Willis Jackson. 3rd Ed. London, Methuen & Company Ltd.; New York, John Wiley & Sons, Inc., 1951. 152 pp., diagrs., figs. $1.75.

This book is a treatise for advanced students of electrical engineering on the applications of transmission lines, both as interconnectors and circuit elements, in microwave equipment. Two appendixes provide data for the construction of a Cartesian grid diagram and of the polar form of diagram. A bibliography of 14 items, supplementary to the footnote references and to a subject index, completes the book. The author is associated with the Electrotechnics Department, The University, Manchester.

Contents: Chapter 1, Some Applications of Transmission Lines at Very High Frequencies. Chapter 2, The Basic Equations for Transmission Lines Propagating in the Principal Mode. Chapter 3, The Propagation Characteristics of Lines. Chapter 4, The Behaviour of Terminated Lines. Chapter 5, Resonant Lines. Chapter 6, Impedance Transformation—The Use of the Circle Diagram Technique.

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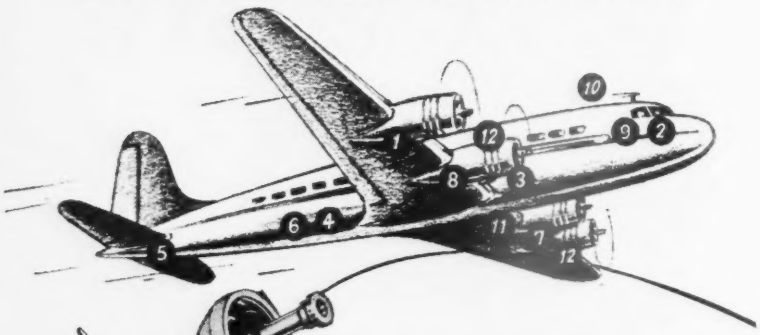

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ELECTRICAL

Light, Photometry, and Illuminating Engineering. William E. Barrows. 3rd Ed. New York, McGraw-Hill Book Company, Inc., 1951. 415 pp., figs. $7.50.

Approximately two-thirds of the material in the latest edition of this textbook for electrical engineering students is new or completely revised. Practically new in content over the previous, 1938 edition are the chapters on Gas, Vapor, and Fluorescent Lamps; Photometric Measurements and Illumination Surveys; Illumination Calculations and Design, Interior Lighting Practice; and Lighting Streets, Highways, and Airways. Extensive revisions have been made in the chapters on Light and Vision, Sources of Light, Principles of Interior Lighting, and Light Control and Application. Much material from publications of the Illuminating Engineering Society and the electrical companies has been used. Illustrations are numerous and detailed, and there are many footnote references. The book concludes with a section of 72 problems and an adequate subject index. The author is Professor Emeritus of Electrical Engineering, University of Maine.

HYDRAULIC

Positive-Displacement Pumps and Fluid Motors. Warren E. Wilson. New York, Pitman Publishing Corporation, 1950. 250 pp., figs. $7.50.

This textbook on the theory of operation and principles of design of positive-displacement hydraulic pumps, motors, and power-transmission systems consists of two parts. The first five chapters form an introduction for the young graduate engineer and give definitions, a classification system, an elementary theory of operation, and a test procedure. The last six chapters develop a more nearly complete theory of operation and apply the theory to a method of test-data analysis, to a method of design, and to the discussion of the operation of hydraulic clutches and transmissions. The author is President, South Dakota School of Mines and Technology.

Contents: Chapter 1, History and Elementary Concepts. Chapter 2, Deviations from Ideal Performance. Chapter 3, Classification of Pumps and Fluid Motors. Chapter 4, Characteristics and Applications of Positive-Displacement Units. Chapter 5, Elementary Performance Calculations. Chapter 6, Elements of Fluid Flow. Chapter 7, Pump and Motor Theory. Chapter 8, Advanced Analysis of Experimental Data. Chapter 9, Design Methods. Chapter 10, Hydraulic Clutches. Chapter 11, Hydraulic Transmissions. Appendix I is a bibliography of over 450 references grouped by year of publication. Appendix II is a list of symbols, and Appendix III is a table of conversion factors for dynamic viscosity. Examples, problems, and footnote references are given throughout.

MATERIALS

Materials Handbook. An Encyclopedia for Purchasing Agents, Engineers, Executives, and Foremen. George S. Brady. 7th Ed. New York, McGraw-Hill Book Company, Inc., 1951. 913 pp. $8.50.

In this edition, data on new materials have been added, and Part 2, which began as an appendix containing such tables as are frequently required for reference, has been developed into a section presenting the elements of material economics. This appendix presents basic data on the economic geography of materials, resources, weights, measurements, physical comparisons, and other information. The previous, 6th edition was published in 1947.

METALS & ALLOYS

The Hardness of Metals. D. Tabor. Oxford, Clarendon Press; New York, Oxford University Press, 1951. 175 pp., figs., tables. $3.00.

The aim of this monograph is to explain hardness measurements in terms of some of the more

basic physical properties of metals. Elastic and plastic characteristics are the terms in which the hardness behavior of metals is expressed; the atomic and crystalline mechanism of elastic or plastic deformation is not dealt with, and practical techniques of measurement are touched upon only broadly. The presentation is intended for physicists, engineers, and metallurgists, but the nonmathematical reader may comprehend the general physical picture because of the emphasis on the physical concepts involved.

Chapter 2, Hardness Measurements by Spherical Indenters. Chapter 3, Deformation and Indentation of Ideal Plastic Metals. Chapter 4, Deformation of Metals by Spherical Indenters; Ideal Plastic Metals. Chapter 5, Deformation of Metals by Spherical Indenters; Metals Which Work-Harden. Chapter 6, Deformation of Metals by Spherical Indenters; "Shallowing" and Elastic "Recovery." Chapter 7, Hardness Measurements with Conical and Pyramidal Indenters. Chapter 8, Dynamic or Rebound Hardness. Chapter 9, Area of Contact Between Solids. Appendixes contain tables of Brinell, Meyer, and Vickers hardness; hardness conversion; hardness and ultimate tensile strength; and typical hardness values of metals and alloys. References are listed at the ends of chapters, and there are name and subject indexes. The author is associated with the Department of Physical Chemistry, Cambridge University.

Magnetic and Electrical Methods of Non-Destructive Testing. D. M. Lewis. London, George Allen & Unwin Ltd., 1951. 242 pp., illus., diagrs., figs. 35*s*.

This comprehensive review was compiled for the Magnetic and Electrical Methods Sub-Committee of the British Iron & Steel Institute. The 118 plates and diagrams of equipment and typical defects as revealed in tests form a useful feature. A brief sketch of the development of nondestructive testing is offered in the Introduction. Part 1, Magnetic Particle Testing, deals with the scope of the method, methods of magnetizing, magnetizing force and current, powders and fluids, inspection procedure, interpretation of powder indications, demagnetization, and examples of typical testing procedures. The topics comprising Part 2 are d.c. search coil methods, a.c. methods, r.f. testing methods, and electrical resistance methods. Magnetic and electrical methods of measuring plate and coating thickness are discussed in Part 3. Part 4 is a survey of magnetic sorting methods, electronic sorting and testing methods, determination of the carbon content of steels, and tribo- and thermoelectric sorting methods. The final sections consist of a list of illustrations; a list of the 274 works cited in the text; three short tabular appendixes on magnetic crack detection in production, typical magnetic characteristics, and examples of suitable testing procedures; and a combined index of subjects and names.

SCIENCES, GENERAL

MATHEMATICS

Finite Matrices. W. L. Ferrar. Oxford, Clarendon Press; New York, Oxford University Press, 1951. 182 pp., figs. $4.00.

This book is written for graduate students and for undergraduates whose degree courses include more matrix theory than a textbook of elementary properties will provide. The author, a Fellow of Hertford College, Oxford, gives an account of the theory of finite matrices, including their invariant factors and elementary divisors, for mathematicians who are not specialists in this particular field. Ordinary numbers of analysis are used, and the demands of an abstract algebra have not generally been considered. The introductory chapter is a résumé of the more elementary properties of matrices. In Chapters 2 to 7, equivalent matrices, equivalent λ-matrices, collineation, infinite series and functions of matrices, congruence, and matrix equations are considered. Chapter 5, Infinite Series and Functions of Matrices, is largely a first essay at a connected account of this part of the theory. Chapter 8 consists of notes on the resolvent of a matrix, positive-definite quadratic forms subject to linear theory, and sets of anticommutative matrices. References are given in the preface, text, and footnotes; there is a 2-page index of topics and some names.

Statistical Decision Functions. Abraham Wald. New York, John Wiley & Sons, Inc., 1950. 179 pp. $5.00.

A knowledge of calculus and some familiarity with the elements of set, measure, and integration theories suffice as mathematical background for reading this presentation of the recently developed general theory of statistical decision functions. Throughout, general ideas and results are

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emphasized rather than specific methods or techniques. The design of experimentation is treated as a part of the general decision problem. The general theory, as presented, allows for multistage experimentation and includes the general multidecision problem. This work is an outgrowth of several previous publications of the author and was written under the sponsorship of the Office of Naval Research. There are a bibliography, 76 references, and a detailed subject and name index. The author is Professor of Mathematical Statistics, Columbia University.

Contents: Chapter 1, The General Statistical Decision Problem: Definitions and Preliminary Discussion. Chapter 2, Zero Sum Two-Person Games with Infinitely Many Strategies. Chapter 3, Development of a General Theory of Statistical Decision Functions. Chapter 4, Properties of Bayes Solutions When the Chance Variables Are Independently and Identifically Distributed and the Cost of Experimentation Is Proportional to the Number of Observations. Chapter 5, Application of the General Theory to Various Special Cases.

Advanced Engineering Mathematics. C. R. Wylie, Jr. New York, McGraw-Hill Book Company, Inc., 1951. 640 pp., figs. $7.50.

Advanced engineering mathematics is interpreted by the author as those branches of mathematics which a student of engineering or applied science normally encounters in the first year or two following his introductory work in calculus. Accordingly, the treatment in this book covers ordinary differential equations, with particular emphasis on linear equations with constant coefficients, Fourier series, operational calculus from the point of view of the Laplace transformation, separable partial differential equations and associated boundary value problems, functions of a complex variable, vector analysis, and numerical methods. A chapter on electrical and mechanical vibrations is included as an illustration of the unification of two seemingly unrelated fields. The stream function and the velocity potential, special flow patterns, the flow past a cylinder, the transformation of a circle into an airfoil, and the force on an airfoil receive treatment in Chapter 14, Analytic Functions and Fluid Mechanics. There are numerous worked examples and figures, and the more than 950 exercises range from formal problems of a purely routine nature to practical problems of considerable complexity. In a 59-page appendix, the author, who is Professor and Chairman, Department of Mathematics and Astronomy, University of Utah, has provided a review of selected topics from algebra and calculus and a glossary of 45 technical terms.

THERMODYNAMICS

Heat and Thermodynamics; An Intermediate Textbook for Students of Physics, Chemistry, and Engineering. Mark W. Zemansky. 3rd Ed. New York, McGraw-Hill Book Company, Inc., 1951. 465 pp., figs. $6.00.

Among the topics that have been more fully discussed in this edition are the temperature concept, the three laws of thermodynamics, natural convection, the phase rule, and certain experimental methods. New topics, not covered in the previous edition (1943), include forced convection with application to the single-current heat exchanger, a treatment of the thermocouple by a method equivalent to that of Tolman and Fine, dielectrics and piezoelectricity, and the physics of very low temperatures.

Thermodynamics. Alfred W. Porter. 4th Ed. With Two New Appendices by W. Wilson. London, Methuen & Company Ltd.; New York, John Wiley & Sons, Inc., 1951. 124 pp., figs. $1.50.

The first edition of this introduction to thermodynamics was published in 1931. In Appendix I of the present edition, Commentary on Porter's Thermodynamics, Wilson has emphasized the importance of the work of Carnot and Clapeyron and the relationship of their work to the later form of thermodynamics. Appendix II is devoted to the application of the first and second laws to black-body radiation.

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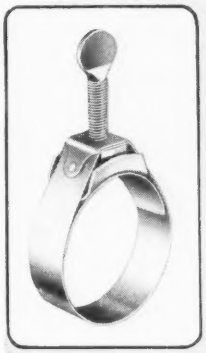

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Personnel Opportunities

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Wanted

Weight Engineer—Applicant must have a thorough knowledge of weight investigation work, including the calculation of complicated aircraft fittings, preparation of aircraft weight studies, and a thorough knowledge of aircraft balance computations, flight ballasting schedules, and normal weight control procedures from the time of conception of design to actual manufacture of prototype and production articles. Several years' actual experience as a weight engineer is required. Submit reply to Personnel Department, Sikorsky Aircraft, Bridgeport, Conn.

Structural Engineer—Having a minimum of 3 to 4 years of extensive aircraft (preferably including some helicopter background) stress analysis experience, preparing stress data in accordance with Air Force, Navy, and C.A.A. specifications requirements. Those having supervisory experience in directing structural designers and draftsmen given special consideration. Only applicants having practical knowledge of formal stress analysis procedures are asked to apply. Submission of personal data should include comprehensive descriptions of previous positions, salary, scope of assignments, and chief interest in aeronautical engineering field. Submit reply to Personnel Department, Sikorsky Aircraft, Bridgeport, Conn.

Structures Engineer—With 2 or 3 years' aircraft experience needed by small expanding company for essential military airplane projects. Must be familiar with loads, methods of analysis, and allowables. Please submit full details, including education, experience, capabilities, availability, salary requirements, etc. Address: Engineering Department, Anderson, Greenwood & Company, Municipal Airport, Houston 17, Tex.

ENGINEERS—The U.S. Naval Air Rocket Test Station has several vacancies in the Engineering Department. **Aeronautical Engineer**—GS-11, $5,400 per annum. Duties: Project Engineer in the Evaluation Branch, Power Plants Division of the Engineering Department. Conduct specialized investigations, usually extensive in nature of the performance of liquid propellant rocket engines, rocket power plants, and their components. Devise special test procedures, make theoretical analyses, supervise the preparation of the test apparatus and the test operation, and prepare evaluation reports on rocket engines or components. **General Engineer**—GS-11, $5,400 per annum. Duties: Head of Facilities Branch, Power Plants Division, Engineering Department. The Facilities Branch makes plans, procures and installs equipment for new testing facilities and for modifications of existing facilities. The work covers all phases from initial planning and layout to actual installations. **Aeronautical Engineer**—GS-9, $4,600 per annum. Duties: Project Engineer in the Evaluation Branch, Power Plants Division of the Engineering Department. Conducts specialized investigations of the performance of liquid propellant rocket engines, rocket power plants, and their components. Devise special test procedures, make theoretical analyses, and prepare evaluation reports on rocket engines or components. **General Engineer**—GS-9, $4,600 per annum. Duties: Project Engineer in the Facilities Branch Engineering Department. The Facilities Branch makes plans, procures and installs equipment for new test testing facilities. The work covers all phases from initial planning and layout to actual installation. **Illustrator (Equipment)**—GS-6, $3,450 per annum. Duties: Illustrator in the Drafting Section of the Engineering Department. Makes original illustrations of mechanical equipment and lays out technical reports and prepares them for publication. Applicants should submit Standard Form 57, Application for Federal Employment, which is available at any Post Office, and forward to the Industrial Relations Officer, Industrial Relations Department, U.S. Naval Air Rocket Test Station, Lake Denmark, Dover, N.J.

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Experienced Aerodynamicists—Able to assume major or full responsibilities for aerodynamic design and testing of projectiles and missiles. Minimum of 2 years' experience will be considered, but emphasis in evaluating qualifications will be placed on individual ability. Address inquiries to D. J. Wishart, Director of Personnel, Aircraft Armaments, Inc., 4415 Reisterstown Road, Baltimore 15, Md.

ENGINEERS—The U.S. Naval Air Rocket Test Station has several vacancies in the Engineering Department. **Aeronautical Engineer**—GS-12, $7,040 per annum. Duties: Head of Evaluation Branch, Power Plants Division of the Engineering Department. Directs specialized investigations of the performance of rocket engines, rocket power plants, or their components. **General Engineer**—GS-11, $5,940 per annum. Duties: Head of Facilities Branch, Power Plants Division, Engineering Department. The facilities branch makes plans, procures and installs equipment for new testing facilities and for modifications of existing facilities. The work covers all phases from initial planning and layout to actual installations. **Aeronautical Engineer**—GS-9, $5,060 per annum. Duties: Project Engineer in the Evaluation Branch, Power Plants Division, of the Engineering Department. Conducts specialized investgations of the performance of liquid propellant rocket engines, rocket power plants, and their components. Devise special test procedures, make theoretical analyses, and prepare evaluation reports on rocket engines or components. **General Engineer**—GS-9, $5,060 per annum. Duties: Project Engineer in Facilities Branch, Engineering Department. The facilities branch makes plans, procures and installs equipment for new testing facilities. The work covers all phases from initial planning and layout of actual installation. **Aeronautical Engineer**—GS-9, $5,060 per annum. Duties: Project Engineer in the evaluation branch, Power Plants Division of the Engineering Department. Con-

The number preceding the notices represents the Box Number of the Institute of the Aeronautical Sciences to which inquiries should be addressed.

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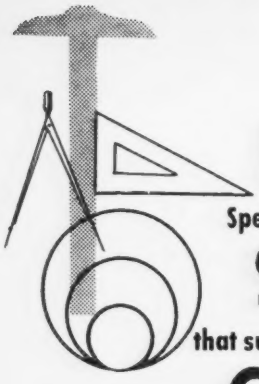

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362. Administrative Engineer—Seventeen years of varied experience in aircraft and automotive design and production. Presently with small research and development organization producing instruments and devices for Wright Air Development Center. Previously Chief, Mobilization Programs Analysis Branch, A.S.U.; Chief Tool Engineer, Brewster Aero Corp. Seeks supervisory or administrative position. Salary, $9,000.

361. Aeronautical Engineer—(Age 47, Italian nationality) Doctor's Degree, Mechanical Engineering and Naval Architecture. Twenty-four years' experience in U.S.A. and Italy. Stress analysis, structural design, aerodynamics, research, complete aircraft project (16 years as Chief Engineer); 7 years of experience teaching structural design of aircraft as university professor; seeks opportunity outside Italy in order to continue working in aeronautics.

360. Engineer—Pilot, commercial license; single and multi-engine land, instrument ratings. Current in reciprocating and jet fighters. M.S. in Aeronautics with honors from CalTech in 1940. Two years as instructor in college, aeronautical engineering. One year air-line maintenance engineer in South America. Eight years' progressive experience in engineering flight test for major air-frame manufacturer.

359. Engineering Pilot—B.S. Aero. Eng., 1942. Age 33, married. Sixteen years of flying experience. Commercial pilot, single and multi-engine land, instrument, and flight instructor ratings. Three thousand hours' total flying time, 2,200 multiengine. One year part-time C.P.T. primary and secondary flight instructor. Three and one-half years' flight-test experience with manufacturer as engineering test pilot. Thorough engineering and flight background in aircraft performance, stability, controllability, and power-plant performance testing. Three and one-half years with air lines as air-line pilot, engineering and maintenance test pilot, and consulting engineer. Experienced in both domestic and overseas air-line piloting. Has thorough working background in flight analysis, with emphasis on aircraft performance as applied to C.A.A. requirements for Air Transport Category. Has engaged in development of Pilots Aircraft Operating Manuals for aircraft manufacturer and air lines. Experienced in electronic and supersonic aircraft development work. Interested in engineering-pilot position with air line or manufacturer

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357. Engineer—B.Aero.E., M.Aero.E., L.L.B. Seven years' experience with large jet-engine manufacturer as technical consultant, project administrator, and engineering supervisor. Detailed knowledge of all types of jet propulsion systems, including turbojets, ram-jets, rockets, and compound cycles. Experienced in supersonic aerodynamics, combustion, and mechanical design. Administrative ability. Presently directing the efforts of 45 technical personnel. Desires economic advancement.

356. Engineering Supervisor—Age 31. Eleven years' experience in aircraft manufacture, air-lines and military aircraft repair bases, covering all types of aircraft. Desires position with future in air-line organization or airplane repair and maintenance center.

354. Aeronautical Engineer—Professor, B.S., M.S., A.F.I.A.S. Presently employed as Chief Engineer of military test development and instructional division as aeronautical consultant and as visiting graduate school professor at a large eastern university. Desires full time research and development, industrial, or teaching work. Over 10 years of aeronautical engineering experience in industry and in teaching. Author of two recent textbooks on aerodynamics, as well as technical papers on stress analysis and aerodynamics which have appeared in the *Journal of the Aeronautical Sciences* and *Aero Digest*. Please advise as to the nature of openings in first letter. Routine or form inquiries will not be considered.

352. Aeronautical Engineering Professor-Development Engineer (M.S.)—Extensive and varied aeronautical background (both administrative and technical) in fixed and rotating wing aircraft. Graduate and undergraduate teaching experience in aerodynamics (classical and supersonic), design, and structures. Many aeronautical publications including textbook. Will consider research and administrative possibilities.

Aeronautical Reviews

(*Continued from page 96*)

A Shock Tube Method of Generating Hypersonic Flows. Abraham Hertzberg. *Journal of the Aeronautical Sciences*, Vol. 18, No. 12, December, 1951, pp. 803–804, 841, illus. 5 references.

Use of a divergent nozzle before the test section to obtain higher Mach Numbers than with a constant-area nozzle; results of exploratory tests with a small shock tube at Cornell Aeronautical Laboratory, Inc.

Canada's Supersonic Wind Tunnel. *Aviation Age*, Vol. 16, No. 3, September, 1951, p. 33, illus. Working sections of the supersonic wind tunnel for the National Research Council of Canada. Interchangeable nozzle sections will provide air speeds up to 5,000 m.p.h.

Influence of Refraction on the Applicability of the Zehnder-Mach Interferometer to Studies of Cooled Boundary Layers. Martin R. Kinsler. *U.S., N.A.C.A., Technical Note No. 2462*, September, 1951. 39 pp., illus. 7 references.

Analysis of the magnitude of refraction effects; application to the design of two-dimensional test sections for studying cooled boundary layers by the interferometric method.

An Instability Problem Arising in Uniform Cantilevered Struts (Investigations in Aeronautics from the Department of Aeronautical Engineering). Harold C. Martin. *Washington, University, Engineering Experiment Station, Bulletin No. 118 (Aeronautical Series No. 1)*, 1951, pp. 95–99, illus. 4 references. Analysis of the stability of a wind-tunnel model support strut, considering the lift and drag forces transmitted to the strut from the model.

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AERODYNAMICISTS—AIRPLANE. Two years of aerodynamics experience required in either subsonic, transonic, or supersonic aerodynamics for work on high performance military airplanes.

STRUCTURES ENGINEERS—AIRPLANE. Two years or more of experience required in either stress analysis, air loads, or physical testing for work on high performance military airplanes.

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